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Potential spray irrigation site in Fauquier County, Virginia

Spray Irrigation of Athletic Fields Using Reclaimed Water: A Review for Fauquier County

Fauquier County Parks and Recreation Department

Stone Project # 041551-W

Spray irrigation of reclaimed water on athletic field in Hawaii

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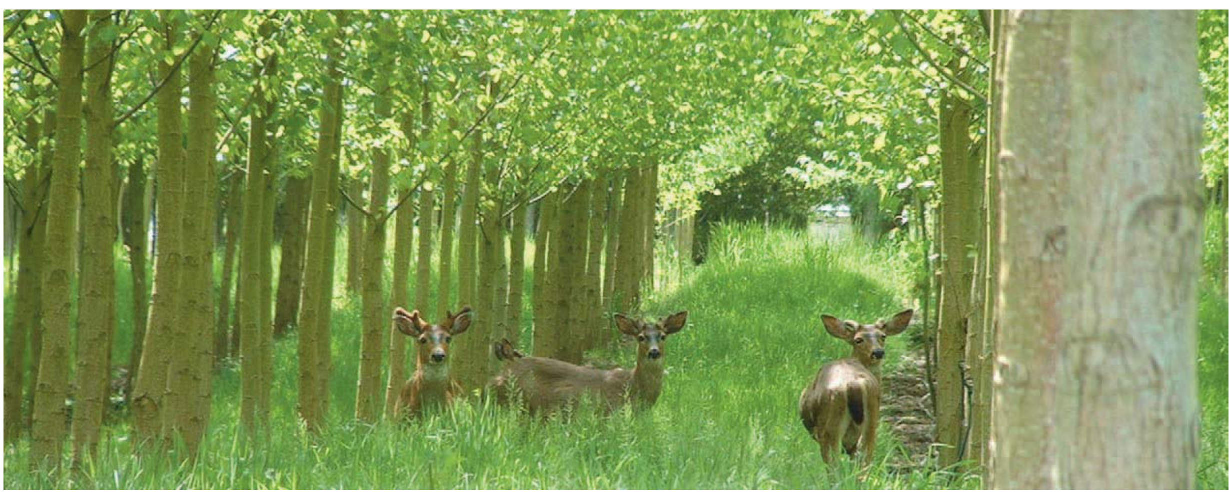

Spray irrigation of a poplar plantation in Woodburn, Oregon

1. INTRODUCTION

Reuse of treated wastewater offers an effective means of conserving high-quality freshwater supplies while helping to meet growing demands for water. Many communities throughout the United States and the world are using or considering water reuse for a wide variety of applications such as landscape and agricultural irrigation (including residential lawns, parks, and athletic fields), toilet and urinal flushing, industrial processing, power plant cooling, wetland habitat creation or restoration, and groundwater recharge. While regulations and guidelines for water reuse vary widely from state to state, they generally require higher levels of wastewater treatment and reliability prior to reuse with high-level uses such as irrigation of parks and schoolyards where the potential for public contact is high.

The Fauquier County Department of Parks and Recreation engaged Stone Environmental, Inc. (Stone) of Montpelier, Vermont to conduct research and develop a report on the reuse of treated wastewater effluent via spray irrigation systems on recreational ball fields. This study includes the following:

- Review information on where water reuse on ball fields is done in the United States, and the applicable regulations
- Review information on where water reuse on ball fields is done in Virginia, and the applicable regulations
- Identify potential environmental and public health impacts
- Survey existing systems in Virginia and elsewhere
- Note public concerns and provide guidelines for public education and outreach
- Review a specific site proposed for water reuse in Fauquier County
- Develop conclusions and make recommendations

2. POTENTIAL RISKS AND IMPACTS

Wastewater is characterized in terms of its physical, chemical, and biological composition. The important constituents of concern in wastewater treatment are listed in Table 1. Secondary treatment standards generally concern the removal of biodegradable organic compounds, total suspended solids, and pathogens. When wastewater is to be reused, treatment standards are more stringent, typically including additional requirements for the removal of refractory organic compounds, heavy metals, and dissolved inorganic solids (Metcalf and Eddy, 2003; US EPA, 2004). The specific effects that constituents of treated wastewater used in spray irrigation systems can have on human health and the environment are discussed in the following sections.

Spray Irrigation of Athletic Fields Using Reclaimed Water:
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Table 1: Principal Constituents of Concern in Wastewater Treatment

Constituent	Basis for Concern
Suspended Solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment
Biodegradable Organics	Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most commonly in terms of BOD (biochemical oxygen demand) and COD (chemical oxygen demand). If discharged untreated to the environment, their biological stabilization can deplete natural dissolved oxygen sources and lead to the development of septic conditions
Pathogens	Communicable diseases can be transmitted by the pathogenic organisms that may be present in wastewater
Nutrients	Both nitrogen and phosphorus are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater
Priority Pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of these compounds are found in wastewater
Refractory Organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides
Heavy Metals	Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused
Dissolved Inorganics	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused

Source: Metcalf and Eddy, 2003.
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2.1. Environmental Impacts

2.1.1. Water Quality Impacts to Soil and Plants

In the eastern United States, irrigation is primarily used to supplement natural rainfall in agricultural fields during dry periods. Irrigation is also used to maintain recreational lands, including parks and golf courses. In recent years, the use of reclaimed water for the irrigation of landscaped areas, parks, and golf courses in urban areas has become more common (Metcalf and Eddy, 2003). Evapotranspiration (the water lost through evaporation from the soil and transpiration from plants) results in salt deposition from the applied water, which can accumulate in the soil profile over time. Physical and mechanical properties of the soil, such as soil structure and permeability, are sensitive to the types of ions present in irrigation water, regardless of whether the water is reclaimed from wastewater effluent (Metcalf and Eddy, 2003). Impacts of irrigation water on the soil are often of concern only if they restrict the use of the water or if they require special management.

The presence of salts affects plant growth in several different ways. Generally, with increasing salinity in the soil, plants spend more energy on adjusting their internal salt concentrations in order to obtain water from the soil, leaving less energy available for plant growth (Metcalf and Eddy, 2003). This problem is more severe in hot and dry regions because plants have a higher water demand than in more humid and temperate climates such as that in Virginia (US EPA, 2004).

In addition to the osmotic effects that can be caused by increased salinity, phytotoxic concentrations of specific ions can build up in irrigated soils. This effect is referred to as “specific ion toxicity” (Metcalf and Eddy, 2003). The ions that are of most concern in reclaimed water from households are boron (from household detergents), and sodium and chloride (particularly where water softeners are used). In severe cases, these specific ions can accumulate to levels causing phytotoxicity in plants (Ayers and Westcot, 1985).

Another effect of increased sodium content is the decline of the physical condition of irrigated soil, including waterlogging, crust formation, or reduced permeability (Metcalf and Eddy, 2003). These effects occur when sodium levels in irrigation water exceed calcium levels by a factor of three or more, because sodium causes soil dispersion and structural breakdown, whereas calcium (and magnesium) have a stabilizing effect on soil structure (US EPA, 2004). If the infiltration rate is reduced enough, plants may not be able to get enough water to grow. This effect can be problematic because spray irrigation systems using reclaimed water are often located on soils that already have low permeability or other limitations.

Maintaining a net downward flux of water and salt out of the root zone is critical to avoiding effects of salinity and specific ions on soils and plants; good drainage is essential in this regard. Precipitation in Fauquier County is expected to be sufficient to leach these constituents through the root zone under most conditions, provided that drainage is adequate. Leaching may also be accomplished by the deliberate over-application of reclaimed water to flush salts away from the root zone (US EPA, 2004). Properly managed, salt accumulation in the spray field is not expected to be a problem in Fauquier County, provided that any high water table conditions are corrected through drainage. Note also that testing sodium levels in reuse water should be performed (the ratio of sodium to calcium should be less than 3:1) and that restrictions on the use of water softeners may be considered.

Trace elements, including copper, zinc, nickel, molybdenum, and cadmium, may also accumulate in the soil over time, depending on soil pH, texture, or other properties (EPA 2004). Assuming irrigated areas are not used to grow food crops or forage, the relevant concern is whether concentrations of these elements may increase to phytotoxic levels. Given that the proposal being considered by Fauquier County is for new construction and will not involve industrial or commercial wastewater, concentrations of these trace elements in reclaimed water are expected to be low. Generally trace element concentrations are low in residential wastewaters, but actual levels depend on homeowner practices—education efforts may be considered to ensure homeowners do not dispose of paints, solvents, and other pollutants down the drain. Monitoring should be conducted to characterize levels of trace elements in the reclaimed water. Based on long-term use of an irrigation site, EPA (2004) recommends the following limits for trace element concentrations in reclaimed water: copper0.2 mg/l; zinc 2.0 mg/l; nickel 0.2 mg/l; molybdenum 0.01 mg/l; and cadmium 0.01 mg/l.

The nutrients in reclaimed water are fertilizer for landscape irrigation. If the nutrients provided are in excess of plant needs, however, they can cause problems. The most beneficial and most frequently excessive nutrient is nitrogen (Metcalf and Eddy, 2003). While excessive nutrients are generally not a concern for turf grasses, excess nutrients, particularly nitrogen, can move through the unsaturated soils into the groundwater (see Section 2.1.2).

Reclaimed water that is disinfected with chlorine prior to application may damage plants if the chlorine content of the water is too high. Chlorine residuals of less than 1 mg/l generally do not affect plants, but residuals of more than 5 mg/l can severely damage plants when reclaimed water is sprayed directly on the foliage (Metcalf and Eddy, 2003).

2.1.2. *Impacts to Groundwater or Receiving Waters*

In humid climates, rainfall and excess irrigation are generally sufficient to leach salts out of the root zone, preventing damage to plants (Metcalf and Eddy, 2003). The efficiency of most well-designed and well-managed irrigation systems is about 80%, meaning that 80% of the water applied leaves the soil through evapotranspiration and the remaining 20% percolates through the root zone to the underlying groundwater (Bouwer *et al.*, 1998). However, any constituents that are not removed during the wastewater treatment process, utilized by plants, or treated by the soil are concentrated in that remaining 20% and delivered to the groundwater.

Pathogens should be removed from wastewater prior to application using spray irrigation, but not all chemicals entering the treatment system are biodegradable—and thus they remain in the treated effluent. The wastewater constituents in spray effluent that can contaminate groundwater include:

- Dissolved salts
- Metals
- Nutrients
- Persistent organic compounds (including disinfection byproducts and emerging constituents of concern such as pharmaceuticals and personal care products).

These contaminants are of particular concern if the groundwater downgradient from the spray irrigation site is used as a drinking water source, or if this groundwater recharges a sensitive surface water resource. High salt concentrations in the irrigation water recharging the groundwater can make the groundwater too salty for drinking, particularly if drinking water is pumped from wells in the upper portion of the aquifer (Bouwer *et al.*, 1998). Depending on the nitrate concentration in the applied spray effluent, nitrate concentrations in the deep percolation water may be higher than the federal 10 mg/l nitrate-N drinking water standard. In fine-grained soils, phosphorus and many heavy metals are usually adsorbed, precipitated, or immobilized in the soil (Bouwer *et al.*, 1998). However, if the soil's capacity to retain these contaminants is exceeded, they could eventually affect groundwater quality.

Little is known about the ultimate fate of disinfection byproducts, pharmaceuticals, and some other persistent organic compounds in groundwater. While some of these compounds are known toxins, carcinogens, or endocrine system disruptors the effects of others on human health and the environment are poorly understood. Groundwater affected by deep percolation water from irrigated areas that contains these chemicals may be deemed unsuitable for potable use in the future (Bouwer *et al.*, 1998).

Over time, irrigation may have hydraulic effects on the area near the irrigation site. As deep percolation water reaches the groundwater aquifer, local groundwater levels will rise, particularly if groundwater velocities beneath the site are very slow or the local water table is shallow (Bouwer *et al.*, 1998). This may be a problem if the water table is close to the surface for example, an increase in the height of the water table by even one foot could be problematic where the permanent water table is at five feet and/or the seasonal water table is at three feet. Without a detailed investigation of site hydrology and groundwater, we cannot evaluate the potential for problematic groundwater mounding beneath the proposed spray field in Fauquier County; however, we believe that this question needs to be addressed.

Conversely, one of the major uses of reclaimed water nationwide is to recharge groundwater aquifers depleted by water supply wells (US EPA, 2004). Encouraging recharge of reclaimed water in the same areas water is withdrawn by pumping avoids inter-basin water transfers and supplements local supply.

2.2. Public Health Impacts

One of the most critical objectives in any water reuse application is to ensure that public health protection is not compromised through the use of reclaimed water. Protection of public health is achieved by:

- Reducing or eliminating concentrations of pathogens in reclaimed water
- Controlling chemical constituents in reclaimed water
- Limiting public exposure (contact, inhalation, ingestion) to reclaimed water (US EPA, 2004).

This section discusses potential public health effects of spray irrigation systems caused by pathogenic organisms. Chemical constituents may also be a concern, but are not as important if the reclaimed water is not to be used for potable reuse, food crop irrigation, or aquaculture (US EPA, 2004). These constituents may be a long-term concern when reclaimed water percolates into groundwater that is ultimately used as a potable water source (see Section 2.1.2).

The potential transmission of infectious disease by pathogenic agents is the most common concern associated with reuse of treated municipal wastewater. While modern wastewater treatment processes largely control the occurrence of waterborne diseases, the potential for disease transmission through water has not been eliminated. The following circumstances must occur in order for an individual to be infected through exposure to reclaimed water:

1. The infectious agent must be present in the community, and thus in the community's wastewater;
2. The agent must survive, to a significant degree, all of the treatment processes to which it is subjected;
3. The individual must directly or indirectly come into contact with the reclaimed water; and
4. The agents must be present in sufficient numbers to cause infection at the time of contact (US EPA, 2004).

The pathogens potentially present in wastewater can be classified into three main groups: bacteria, parasites (protozoa and helminthes), and viruses. Table 2 lists some of the infectious agents potentially present in wastewater, along with the diseases associated with each organism.

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Table 2: Representative Waterborne Infectious Agents of Public Health Concern

Organism Type	Representative Organisms	Major Disease
Bacterial	*Salmonella* spp.	Typhoid, paratyphoid
	Shigella	Bacillary dysentery
	Clostridium perfingens	Gastroenteritis
	Campylobacter	Gastroenteritis; can lead to Guillain-Barre syndrome
	E. coli O157:H7 , and other serogroups	Dysentery, hemolytic uremic syndrome, gastroenteritis
	Yersinia enterocolitica	Gastroenteritis, abdominal pain
Enteric Viruses	Enteroviruses	Paralysis, meningitis, respiratory illness, myocarditis, gastroenteritis, infectious hepatitis
	Rotavirus	Gastroenteritis
	Adenovirus	Gastroenteritis
	Caliciviruses	Gastroenteritis
	Norovirus	Gastroenteritis
	Astrovirus	Gastroenteritis
Protozoa	*Giardia lamblia*	Diahrrhea
	Cryptosporidium parvum	Gastroenteritis, flu-like symptoms to severe illness
	Naegleria fowleri	Headache, fever, nausea, vomiting, amoebic meningoencephalitis
	Entamoeba histolytica	Amoebic dysentery

Source: WERF, 2004; US EPA 2004.

Bacteria are microscopic organisms ranging from 0.2 to 10 μm in length (US EPA, 2004). Three of the more common bacterial pathogens found in raw wastewater are *Salmonella spp.*, *Shigella spp*., and *Escherichia coli O157:H7* (a pathogenic strain in the abundant and mostly innocuous *E. coli* bacteria group); these organisms have caused drinking water-related outbreaks with significant numbers of infections and multiple deaths (US EPA, 2004). Bacteria levels in wastewater can be significantly lowered through "removal" and “disinfection” processes. Bacteria can be removed from wastewater through settling processes in septic tanks and during secondary treatment, or through filtration processes using sand filters, fabric or textile filters, or membrane filters (US EPA, 2004). Bacteria can be inactivated through the use of chemical or energy agents, such as free chlorine, ultraviolet (UV) light, chloramines, or ozone (Metcalf and Eddy, 2003). These agents either destroy bacterial cells or interfere with the cells’ reproductive activity.

Parasites, unlike many bacteria, cannot multiply in the environment. They require a host to reproduce and thus are present in wastewater as spores, cysts, oocysts, or eggs—which are often resistant to environmental stresses like drying, heat, and sunlight (US EPA, 2004). Parasites can also be removed from wastewater using the removal and inactivation processes described above; however, commonly used disinfectants like chlorine are not as effective against parasites as they are against bacteria and viruses. Ultraviolet radiation has been shown to be effective against these pathogens at roughly the same dose as required to inactivate some bacteria (Metcalf and Eddy, 2003).

Viruses are very small parasites that are able to multiply only within a host cell. In general, viruses are more resistant to environmental stresses than many bacteria, although some viruses persist only for a short time in wastewater. Because of the small size of most viruses, sedimentation and filtration processes are less effective at removing them from wastewater (US EPA, 2004). Most disinfectants are effective against viruses at relatively low concentrations and contact times, although relatively high UV light levels are required to inactivate viruses compared to bacteria and protozoa (US EPA, 2004).

2.2.1. Pathogens in Reclaimed Water

A number of studies have been conducted regarding the presence of pathogens in reclaimed water. Two recent examples include studies in St. Petersburg, Florida, and in Fairfax County, Virginia. At a large-scale conventional reuse treatment facility in St. Petersburg, Florida, the effectiveness of deep-bed sand filtration and chlorine disinfection were assessed through monitoring naturally occurring bacteria, protozoa, and viruses, as well as through studies using seeded indicator organisms (Rose *et al.*, 1996). At the Upper Occoquan Sewage Authority in Fairfax County, Virginia, several sites at the advanced wastewater reclamation plant were tested over one year for several different pathogens; the treatment processes at this plant included multimedia filtration, chemical lime treatment, and chlorine disinfection (Rose *et al.*, 2000). A summary of the influent and effluent microbiological quality for both studies is shown in Table 3. The results of these studies and others indicate that commonly employed treatment practices are capable of significantly reducing or eliminating these pathogens. Enterovirus, *Crytosporidium*, and *Giardia* were reduced by a minimum of 99.95% (*Cryptosporidium* in St. Petersburg) and taken together by an average of 99.99%.

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Table 3: Pathogens in Untreated and Treated Wastewater

		Untreated Wastewater		Reclaimed Water	
City	Organism	% Positive	Average Value	% Positive	Average Value
St. Petersburg, Florida	Enterovirus (PFU/100 mL)	100	1,033	8	0.01
	Cryptosporidium (oocysts/100 mL)	67	1,456	17	0.75
	Giardia (cysts/100 mL)	10	6,890	25	0.49
Upper Occoquan, Virginia	Enterovirus (PFU/100 mL)	100	1,100	0	0
	Cryptosporidium (oocysts/100 mL)	100	1,500	8.3	0.037
	Giardia (cysts/100 mL)	100	49,000	17	1.1

Source: US EPA, 2004 and references therein.

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Data presented on protozoan pathogen levels in reclaimed water may be misleading because detected organisms may not be viable. Table 3 reports detected oocysts of *Cryptosporidium* and *Giardia*, but does not distinguish between non-viable organisms and organisms capable of infection. This distinction may be lost in reporting of test results. For example, an article in the Orlando *Sentinel* (September 16, 2002) had the headline "Reclaimed Water Teeming with Parasites." The reporter, Kevin Spears, refers to Florida's 100,000 lawns and 400 golf courses irrigated with reused water and says that the practice "may spread potent germs through sprinklers." He reports, "From among utilities in Central Florida, tests detected 2,786 *Giardia* cysts at a Winter Springs plant, 197 oocysts of *Crytosporidium* at a Kissimmee plant, and a Palm Bay plant reported 663 *Giardia* cysts."

The *Sentinel* article also quotes authorities who say the detections are no cause for alarm: David York of Florida's Department of Environmental Protection points out that there is no documentation of any disease. Dr. Bahman Sheikh, a long-time researcher of water reuse, had an email correspondence with Spears after the article in which he pointed out, "Research has shown conclusively and repeatedly that the remaining organisms detected in recycled water, after filtration and disinfection, are non-viable, hence incapable of causing infection...Research at Monterey, California ... and at Los Angeles County Sanitation Districts has conclusively shown that detected cysts and oocysts are just dead bodies. They are left-over from the heavy doses of disinfectant in the treatment process."

A recent study by Rose *et al.* (2004) indicates that pathogen removal and inactivation may be less complete than Dr. Sheikh concludes. The study found "cultivatable" enteric viruses, *Crytosporidium*, and *Giardia* in final reclaimed effluents. Four of six water reclamation facilities studied yielded reclaimed water samples testing positive for infectious *Crytosporidium* oocysts, and infectious

Crytosporidium oocysts were detected in 30% of all reclaimed water samples collected. Rose *et al.* estimate that 10-30% of *Crytosporidium* and 1-3% of *Giardia* oocysts remained infectious through biological treatment, filtration, and disinfection. However, no infectious oocysts of *Cryptosporidium* or *Giardia* were detected in reclaimed water from either of the two plants providing UV disinfection.

Chlorine and UV disinfection in combination resulted in effluent with the best microbial quality in the Rose *et al.* (2004) study. Rose *et al.* note that extended contact times (*i.e.,* 70-90 minutes with 4-6 mg/l of residual chlorine) are most effective at reducing viruses and bacteria. UV disinfection was less effective at reducing bacterial indicators, but more effective at reducing protozoa (*Crytosporidium* and *Giardia)*. Significantly, chlorine disinfection was relatively more effective at inactivating common indicator bacteria (*e.g.*, fecal coliform) than the protozoa, suggesting that indicator bacteria alone are not adequate indicators of wastewater pathogens and should be supplemented with testing for specific protozoa. While exposure to reclaimed water presents some risk, according to Rose *et al.* (2004) this risk "may be very low and quite acceptable to most populations."

2.3. Aerosols

Aerosols are particles less than 50 μm in diameter that are suspended in air. Viruses and many bacteria are in this size range; thus, the inhalation of aerosols is a possible direct means of human infection (US EPA, 2004). Aerosols are a concern where reclaimed water is applied to urban or agricultural sites using sprinkler irrigation systems. One of the most comprehensive aerosol studies was conducted near Lubbock, Texas in the mid-1980s (Camann *et al.*, 1986). At this site, undisinfected trickling filter effluent was sprayed on a 1500-hectare farm. The spray irrigation resulted in significantly elevated air densities of fecal coliforms, fecal streptococci, mycobacteria, and coliphage for at least 650 feet downwind of the farm. While disease surveillance found no obvious connection between self-reported illnesses and degree of aerosol exposure, blood testing indicated a slight increase in the rate of viral infections in individuals who had a high degree of exposure to aerosols (Camann *et al.*, 1986; Ward *et al.*, 1989).

For intermittent spraying of disinfected reclaimed water, occasional inadvertent contact should pose little health hazard from inhalation. No documented disease outbreaks have resulted from the spray irrigation of disinfected reclaimed water (US EPA, 2004). However, several design and operational controls can be used to limit exposure to aerosols, including:

- Setback distances / buffer zones
- Windbreaks, such as trees or walls

- Low-profile sprinklers
- Spray nozzles with large orifices to reduce fine mist formation
- Spraying only during periods of low wind velocity
- Irrigating during off-hours, when the public or employees would not be in areas subject to aerosols or spray

2.3.1. Incidences of Infectious Disease Related to Wastewater Reuse

Epidemiological investigations have generally focused on the use of raw or minimally treated wastewater for food crop irrigation, health effects on farm workers who routinely contact minimally-treated wastewater used for irrigation, and the health effects of aerosols from spray irrigation sites using undisinfected wastewater (US EPA, 2004). These studies provided evidence that such practices can transmit disease (Feachem *et al.*, 1983; Shuval *et al.*, 1986). However, there have been no confirmed cases of infectious disease resulting from reclaimed water use in the U.S. where the use has been in compliance with appropriate regulatory controls (US EPA, 2004).

2.4. Other Risks and Problems

Clogging problems have been reported with both spray and drip irrigation, particularly with secondary wastewater effluent. Biological growth in sprinkler heads, emitter orifices, or supply lines causes plugging, as do heavy concentrations of algae and suspended solids (Metcalf and Eddy, 2003).

Reused water is not intended for direct potable reuse. Care must be taken to prevent cross connections that allow accidentally the reused water to be drawn into the potable water supply and to prevent accidental use of reused water as drinking water.

3. SPRAY IRRIGATION REGULATIONS AND GUIDELINES IN THE UNITED STATES

This section describes the state of current regulations and guidelines concerning wastewater reuse in the United States.

3.1. National Guidelines

The US Environmental Protection Agency (EPA) recently published an updated version of its 1992 guidelines for water reuse (US EPA 2004). The document summarizes state regulations and guidelines and shows some of the changes that have taken place in the regulations and guidelines since 1992. It also summarizes practices in many other countries. There are no federal regulations for water reuse. The guidelines cover wastewater reuse for many different purposes, including:

- Urban irrigation
- Fire protection in urban areas
- Industrial reuse for cooling water, boilers, or process water
- Agricultural irrigation
- Environmental and recreational reuse in wetlands, impoundments, and stream augmentation, and
- Groundwater recharge

Spray irrigation of athletic fields falls under the category of "unrestricted urban reuse," that is, reuse without restrictions on public access to the irrigated areas, where public exposure to reuse water may be high. Where it is more feasible to restrict public access to the irrigated areas, as with golf courses, applications are referred to as "restricted urban reuse". Unrestricted urban reuse applications are typically subject to the highest treatment standards.

Twenty-eight states have either guidelines or regulations governing unrestricted urban reuse of wastewater (Table 4). Both prescriptive and performance-based regulations and guidelines are used. Note that Virginia is considered to have no specific reuse regulations or guidelines. In those states that employ prescriptive guidelines or regulations, which specify the treatment process to be used, secondary treatment plus disinfection is the minimum standard. Most states require further treatment, *e.g*., oxidation, coagulation, and filtration. Texas uses performance-based regulations, which allow any treatment process to be used to achieve the water quality standards that are specified. In Washington State, reclaimed water is not considered wastewater (US EPA, 2004). Aspects of regulations in six states with long-term experience and successful water reuse programs are summarized in Table 5, along with the federal guidelines. The US EPA bases its guidelines on experience with reuse systems both in the US and internationally; data from research, pilot, and demonstration plants; literature review, including review of state regulations; what is attainable; and sound engineering practice.

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Table 4: Summary of State Reuse Regulations and Guidelines

State	Regulations	Guidelines	No Regulations or Guidelines[1]	Change from 1992 Reuse Guidelines	Unrestricted Urban Use	Restricted Urban Reuse
Alabama		✓		N		✓
Alaska	✓			NR		
Arizona	✓			U	✓	✓
Arkansas		✓		N	✓	✓
California[2]	✓			U	✓	✓
Colorado	✓			GR	✓	✓
Connecticut			✓	N		
Delaware	✓			GR	✓	✓
Florida	✓			N	✓	✓
Georgia		✓		U	✓	✓
Hawaii		✓		U	✓	✓
Idaho	✓			N	✓	✓
Illinois	✓			U	✓	✓
Indiana	✓			U	✓	✓
Iowa	✓			NR		✓
Kansas		✓		N	✓	✓
Kentucky			✓	N		
Louisiana			✓	N		
Maine			✓	N		
Maryland		✓		N		✓
Massachusetts		✓		NG	✓	✓
Michigan	✓			N		
Minnesota			✓	N		
Mississippi			✓	N		
Missouri	✓			N		✓
Montana	✓			GR	✓	✓
Nebraska	✓			GR		✓
Nevada	✓			GR	✓	✓
New Hampshire			✓	N		
New Jersey		✓		RG	✓	✓
New Mexico		✓		N	✓	✓
New York		✓		N		
North Carolina	✓			U	✓	✓
North Dakota		✓		U	✓	✓
Ohio		✓		NG	✓	✓
Oklahoma	✓			GR		✓
Oregon	✓			N	✓	✓
Pennsylvania		✓		NG		
Rhode Island			✓	N		
South Carolina	✓			GR	✓	✓
South Dakota		✓		N	✓	✓
Tennessee	✓			N	✓	✓
Texas	✓			N	✓	✓
Utah	✓			U	✓	✓
Vermont	✓			N		
Virginia			✓	N		
Washington		✓		U	✓	✓
West Virginia	✓			N		
Wisconsin	✓			N		
Wyoming	✓			U	✓	✓

Source: Adapted from US EPA, 2004.

Notes: (1) Specific regulations on reuse not adopted; however, reclamation may be approved on a case-by-case basis

(2) Has regulations for landscape irrigation excluding residential irrigation; guidelines cover all other uses

N = No change NR = Changed from no guidelines or regulations to regulations

U = Updated regulations or guidelines NG = Changed from no guidelines or regulations to guidelines

GR = Guidelines changed to regulations RG = Changed from regulations to guidelines

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Table 5: Summary of Selected Guidelines and Regulations for Unrestricted Urban Reuse Water Quality

	Federal Guidelines	Arizona	California	Florida	Hawaii	Nevada	Texas	Washington
Treatment	Secondary treatment, filtration, and disinfection	Secondary treatment, filtration, and disinfection	Oxidized, coagulated, filtered, and disinfected	Secondary treatment, filtration and high-level disinfection	Oxidized, filtered, and disinfected	Secondary treatment and disinfection	NS	Oxidized, coagulated, filtered, and disinfected
BOD_5	≤ 10 mg/L	NS	NS	20 mg/L $CBOD_5$	NS	30 mg/l	5 mg/l	30 mg/L
TSS	NS	NS	NS	5.0 mg/L	NS	NS	NS	30 mg/L
Turbidity	≤ 2 NTU	2 NTU (avg) 5 NTU (max)	2 NTU (avg) 5 NTU (max)	NS	2 NTU (max)	NS	3 NTU	2 NTU (avg) 5 NTU (max)
Coliform Type	**Fecal**	**Fecal**	**Total**	**Fecal**	**Fecal**	**Fecal**	**Fecal**	**Total**
Coliform Standard or Guideline	None detectable 14/100 mL (max)	None detectable (avg) 23/100 mL (max)	2.2/100 mL (avg) 23/100 mL (max in 30 days)	75% of samples below detection 25/100 mL (max)	2.2/100 mL (avg) 23/100 mL (max in 30 days)	2.2/100 mL (avg) 23/100 mL (max)	20/100 mL (avg) 75/100 mL (max)	2.2/100 mL (avg) 23/100 mL (max)

Source: Adapted from US EPA, 2004.
Notes: NS = not specified by federal guideline or state regulation
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Date/init: 03-04-05 anm

3.1.1. Guidelines for Managing Cross-Connections and Other Management Practices

If there is cross-connection of potable water supplies with reused water supplies, the reused water could contaminate the potable water. The federal guidelines identify five main ways of safeguarding public health from accidental contamination of potable water or drinking of reused water:

- Identification of pipes and components
- Separation distances from potable water pipes
- Prevention of ability to tie into reused water pipes for potable uses
- Backflow prevention
- Safeguards for converting potable pipe to non-potable use (US EPA, 2004)

Identification of pipes and components. It is important that all pipes and components of the reused water system be clearly identified with what they contain. Purple is a color that is often used to distinguish reused water pipes. Words can also be used, with pipes stamped "CAUTION—NON-POTABLE WATER – DO NOT DRINK" or some similar warning. The Florida Department of Environmental Protection requires that labels on hose bibs, valves, and outlets contain the words “Do not drink” and, in Spanish, “No beber.” A typical sign at a valve reads “IRRIGATION WITH RECLAIMED WATER, DO NOT DRINK.”

Separation distances from potable water pipes. A general rule is for 10-foot separation horizontally and a 1-foot vertical separation between potable and non-potable water lines, with the potable line above the non-potable line if feasible. In Florida, the horizontal separation distance between the pipes is 5 feet, center to center, with at least 3 feet between pipe walls.

Prevention of ability to tie into reused water pipes for potable uses. Hose bibs are generally not allowed on non-potable systems, to prevent accidental use of the water as potable water. Florida regulations allow bibs below ground in a locking box, or bibs that require special tools to operate. In California, the Irvine Ranch Water District uses quick-coupling valves for connections to reused irrigation water.

Backflow prevention. Various backflow prevention devices can be used on the potable water supply, to keep the reused water from flowing into it if an illegal connection is made between the two systems. Air gaps and double-check valves are among the devices used. The American Water Works Association recommends reduce-pressure principal backflow prevention assemblies.

Safeguards for converting potable pipe to non-potable use. When existing potable lines are converted to non-potable use, tracers or some other method should be used to make sure that there are no cross-connections between the potable and non-potable water supplies.

Other. Another management practice, in regulations from the South Island Public Service District in Hilton Head, South Carolina, is to isolate eating and drinking areas and sources from areas irrigated with reused water (South Island PSD, 2005). Protections are in place against both contamination via overspray and direct application. Drinking fountains are to be relocated away from the spray irrigation or protected by a structure, and reused water irrigation is not to take place “near food establishments or public facilities such as picnic tables.” No separation distance is specified in the regulations.

3.2. Virginia State Regulations

The Virginia Pollution Abatement Permit Program issues Virginia Pollution Abatement (VPA) permits for land application of municipal wastewater. The authority for the VPA permits comes from the Federal Clean Water Act, Virginia Code 62.1-44.15 through 44.30, Virginia Administrative Code 9 VAC 25-31-10 et seq. These regulations do not include

technical design standards. For wastewater treatment systems with design flows of 40,000 gallons per day (gpd) or greater, the applicable design, construction, operation, and maintenance and monitoring standards regulations are the Commonwealth of Virginia Regulations, Commonwealth of Virginia, State Water Control Board, 9 VAC 25-790, Sewage Collection and Treatment Regulations (adopted December 4, 2003; effective February 12, 2004), available electronically at:
http://leg1.state.va.us/000/reg/TOC09025.HTM#C0790.

9 VAC 25-790-880—Land Treatment includes descriptions of information needed for a permit application, including relevant sections regarding site design (Section B), site features (Section C), land treatment methods (Section D), treatment system features/criteria (Section F), design loadings (Section G), field area design (Section H), and low-intensity design (Section I). Following are brief descriptions of some of the key sections of the regulations.

- **D. Land treatment methods.** The proposed spray irrigation system is considered a "Irrigation—slow rate" method: "Wastewater may be applied by spraying, flooding, or ridge and furrow methods. Irrigation methods are designed not to discharge to surface waters."
- **F. Features.** This section describes basic treatment standards, buffer zone requirements, required storage volumes, and the minimum reserve area.
    - "Biological treatment that will produce an effluent either with a maximum BOD_5 of 60 mg/l or less, or be of such quality that can be adequately disinfected, if necessary, shall be provided prior to natural treatment, including use of conventional unit operations prior to the land application of treated effluent and advanced treatment prior to reuse. Disinfection may be required following or prior to land application and other natural treatment. If spray irrigation equipment is utilized, adequate aerosol management including pre-disinfection shall be provided."
    - Buffer zones around field areas are based on Fecal Coliform counts in reclaimed water. For the category of no buffer distance, as in the case of ball fields, the Fecal Coliform count is 2.2/100 ml or less (exceeded by no more than 10% of samples tested). No application is allowed during occupation of the field area. Transient public use may occur after a three-hour drying period following application.
    - Holding periods and volumes are also described, including a minimum holding period of 120 days required when climatic data is not available.
    - The reserve area is also discussed. The minimum size of the reserve area is 25% of the design field area, and this reserve area "shall be capable of being used as a functional area within 30 days of notice."
- **G. Design loadings.** This section describes how to develop loading rates and includes a water balance calculation that considers design precipitation plus

effluent applied equal to evapotranspiration plus hydraulic conductivity of receiving soils.

- **H. Field area design.** This section describes basic parameters related to field layouts for application and resting, developing a groundwater monitoring system for the site, and agriculturally related soil tests.
- **I. Low intensity design.** This section describes slope and soils criteria for the irrigation field area and aspects of the spray irrigation system, including provisions for uniform effluent distribution, freezing and corrosion prevention, and use of low trajectory spray nozzles and avoidance of high winds to minimize spread of aerosol mists. The irrigation field "should be as flat as possible with maximum slopes of 5% or less." Special precautions shall be taken when it is necessary to locate field areas on steeper slopes, not to exceed 12%. The irrigation field area shall be located a minimum of 50 feet from all surface waters. Soils criteria include:
    - "Five feet of well-drained loamy soils are preferred. The minimum soil depth to unconsolidated rock should be three feet. The hydraulic conductivity should be between 0.2-6 inches/hour."
    - "The minimum depth to the permanent water table should be five feet. The minimum depth to the seasonal water table should be three feet. Where the permanent water table is less than five feet and the seasonal water table is less than three feet, the field area application rate shall be designed to prevent surface saturation. In addition, underdrain and groundwater pumping equipment may be required."

3.3. Virginia State Permitting Process

The process for 9 VAC 25-790-80, Certificate to Construct (CTC) Procedures, includes the following steps:

1. Submission of a CTC application
2. A preliminary engineering conference
3. Establishment of the reliability classification
4. Submission and evaluation of a preliminary engineering proposal or concept (9 VAC 25-790-940. Preliminary Engineering Report)
5. Submission and evaluation of plans, specifications, design criteria and other data
6. Evaluation of an operation and maintenance (O&M) manual
7. Evaluation of a sludge management plan

Once the CTC is approved, construction can begin, following the approved plans, specifications, and permit conditions. Following acceptable construction and receipt of certifications of construction from the engineer, along with other data specified in the CTC permit, a Certificate to Operate (CTO) will be issued that includes operation, maintenance, and monitoring requirements.

Permits are issued by the Virginia Department of Environmental Quality (DEQ), Office of Wastewater Engineering through their Northern Regional Office for the Northern Area in Woodbridge, Virginia.

3.4. Other State of Virginia Regulations

The Virginia Department of Health (VDH), through its county offices, may have jurisdiction on the proposed project in Fauquier County, although exact levels of involvement vary on a county-by-county basis (A. Jantrania, personal communication, 2005). The Environmental Health District Manager, Dr. Charles Sheppard, confirmed that VDH does not have direct jurisdiction over the project (C. Sheppard, personal communication, 2005). Dr. Sheppard indicated that VDEQ might ask for VDH review and comments on the proposed design, and possibly for assistance regarding the soils review from the Fauquier County Department of Health.

The Virginia DEQ issued Interim Guidance #01-2005, Spray Irrigation and Reuse of Wastewater, on January 18, 2001. This guidance precedes the latest version of the technical regulations, and does not address the proposed use on ball fields. The guidance document needs work and may not be the best reference for how to proceed with this type of proposal (A. Westernak, personal communication, 2005).

3.5. County Government Regulations

Under the current proposal, the County Board of Supervisor's will own the fields and land where the spray system is located. The County Water and Sanitation Authority (WSA) will take over ownership of the collection, treatment, storage, and dispersal system, and will have authority to charge and collect fees and operate, maintain, and monitor the system in accordance with the permit and the operation and maintenance (O&M) manual. The Department of Community Development contains the Planning and Zoning departments and issues permits under the Fauquier County Subdivision Ordinance and the Zoning Ordinance. This department may conduct an informal review of the soils and site layout for the spray fields, and will be involved with subdivision and development approvals.

Specific county regulations and responsibilities are outlined below:

- Water and Sanitation Authority
    - Article III, Sec. 17-40 describes procedures for a publicly owned treatment works (POTW) within the county, and enables WSA to comply with applicable state and federal laws and the permit process. It does not specifically address spray irrigation dispersal, but is geared towards surface water discharges.
        - "This article sets forth uniform requirements for direct and indirect users of the wastewater collection and treatment systems of the publicly owned treatment works (POTW) within the county,

or serving the county, and enable the Fauquier County Water and Sanitation Authority (the authority) to comply with all applicable state and federal laws, including the Clean Water Act (33 United States Code 1251 et seq.) and the General Pretreatment Regulations (40 CFR, Part 403)."

  - Sec. 17-41 (e): "The authority shall have the right to establish local pollutant limits to protect against pass through and interference."
  - The WSA will be involved with the review and approval process throughout design and construction and startup operations.

- The County Community Development Department administers the Fauquier County Zoning and Subdivision Ordinances. This project qualifies for a Major Site Plan Review. The Zoning Division coordinates the review and approval of site plan applications through the Technical Review Committee (TRC).

Commonwealth of Virginia
Department of Environmental Quality (DEQ)
- Virginia Pollution Abatement Permits
- Technical Regulations: Sewage Collection and Treatment Regulations

Department of Health (VDH)
- No direct jurisdiction
- Informal reviews (including soils) at Rappahannock-Rapidan Health District and Fauquier County Health Departments

Fauquier County
Board of Supervisors
- Ownership of recreational fields

Department of Parks and Recreation
- Park site design
- Management of recreational fields

Department of Community Development
- Zoning and subdivision ordinances
- Building permits

Water and Sanitation Authority (WSA)
- Review plans
- Construction oversight
- Ownership and operation/maintenance

Figure 1. State and County Stakeholders and Regulatory Responsibilities

3.6. Other States' Rules and Guidelines

Currently, there are no federal regulations directly governing water reuse practices in the U.S.; however, water reuse regulations and guidelines have been developed by many individual states. Table 4 contains a summary of all 50 states with general information about whether each state has regulations or guidelines, and whether each state's guidelines or regulations support urban reuse (including use of reclaimed water on athletic fields). In states with no specific regulations or guidelines on water reclamation and reuse, projects may still be permitted on a case-by-case basis.

Regulations and guidelines vary considerably from state to state. States such as Arizona, California, Colorado, Florida, North Carolina, and Washington have developed regulations or guidelines that strongly encourage water reuse as a water resources conservation strategy. Other states have developed water reuse regulations with the primary intent of providing a disposal alternative to discharge to surface waters, without considering the management of reclaimed water as a resource. While a comprehensive and detailed review of the regulations and guidelines for water reuse in all 50 states is outside the scope of this report, other workers have compiled this information. Appendix A to this report contains a detailed summary of guidelines and regulations for unrestricted urban water reuse from the recent US EPA *Guidelines for Water Reuse* (2004). A similarly detailed state-by-state summary, compiled during 2001-2003, is available on the Internet (Hilger, 2004).

4. SURVEY OF EXISTING SYSTEMS

Of the 28 states with either guidelines or regulations on water reuse, contacts were made in six states plus Virginia to collect representative information on spray irrigation of reclaimed water on ball fields. Information was collected on systems in Florida and California because these states have the most experience with water reuse systems. Washington State was contacted because of the state's climate and history of water reuse. Pennsylvania, North Carolina, and South Carolina were all contacted because these are neighboring states with more experience with water reuse than Virginia.

In the course of our research we learned that the Water Reuse Association, a group promoting the reuse of water, is completing a comprehensive study of water reuse on ball fields, parks, and other public places that is due in April, 2005. Jeff Mosher, a spokesman familiar with the study, said that the study identified 1,600 cases of irrigation with reused water and no documented public health problems.

4.1. Systems in Virginia

The Virginia DEQ online project database was searched for Certificates To Operate (CTO) for water reuse systems; however, no permit records were listed. One approved project is listed in York County (YR STP Water Reclamation Facility Phase I CTO), but the DEQ review engineer indicated that this reuse was for industrial purposes and did not include spray irrigation (Garnett, personal communication, 2005).

One potential system of interest in Virginia is the Bristow Manor Golf Club Wastewater Treatment Plant (WWTP) in Bristow, Prince William County, Virginia. Bristow Manor owns and operates the WWTP and a spray irrigation system that distributes treated effluent to 5.2 acres of the golf club site being used as a driving range. The permit for this system was issued in July 1994; the system has design flows of 10,700 gpd and serves the golf club and approximately 22 residences. The State Water Control Board Enforcement Action issued a Special Order By Consent to Bristow Manor Limited Partnership for operation of the system (VPA00012) in June 2004. The findings of facts and conclusions of Law Section C (2) indicates, "The Board has evidence to indicate that Bristow Manor has violated the Regulation and the Permit by failing to: (1) properly operate and maintain the treatment works and spray irrigation system; (2) maintain required minimum freeboard in the WWTP stabilization pond; (3) comply with required effluent application rates; (4) sample, monitor and/or report required effluent, soil and groundwater permit parameters; (5) provide adequate operating staff for the WWTP; and (6) record monitoring activities."

4.2. Systems in Other States

4.2.1. California

California, where frequent droughts have restricted potable water availability, is one of the leading states in reuse of water (US EPA, 2004). In fact, where reused water is available, California law declares it to be "a waste or an unreasonable use" to employ potable water for uses "including, but not limited to, cemeteries, golf courses, parks, highway landscaped areas, and industrial and irrigation uses" and prohibits it (California Department of Health Services, 2001). California, like many other states, has different reclaimed water quality and treatment requirements depending on the type of reuse application. Standards for irrigation of unrestricted urban areas are equivalent to standards for irrigation of food crops and substantially higher than standards for irrigation of restricted urban areas or agricultural areas with non-food crops (*e.g.*, sod farms, ornamentals). Regulations for reuse of wastewater are summarized in Appendix A.

The Irvine Ranch Water District in Irvine, California produces reclaimed water at the Michelson Water Reclamation Plant[1]. This water carries an Unrestricted Use Permit from the California Department of Health Services, which allows it to be used for most purposes, including swimming. Over 5,650 acres of landscaping are irrigated, including parks, golf courses, school playfields, athletic fields, and common areas maintained by homeowner associations. By the year 2000, the district was reporting that reused water comprised over 20% of all water use within the district (Irvine Ranch Water District n.d.).

Understanding the importance of keeping users of reclaimed water informed, Irvine Ranch maintains frequent contact with its customers. They publish a monthly newsletter containing information about water use and landscaping, and use it to advertise "water awareness tours" of their water reclamation facilities[2]. Irvine Ranch's four-page report on quality of reclaimed water is also easy to read and attractively laid out (Irvine Ranch Water District n.d.; see also Appendix B).

In Santa Rosa, water from the Laguna Subregional Treatment Plant is used to irrigate—among other facilities—ten parks, eight schools, and a local university, according to plant operator Randy Piaza. The water meets the tertiary treatment standards of the California reuse regulations. They have been operating with reused water for ten years and are not aware of any public health impacts, according to

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[1] More information at http://www.irwd.com/Reclamation/ReclamationFrame.html

[2] The newsletters and other publications are at http://www.irwd.com/FreeServices/Publications.html. See the August 2004 newsletter for a representative promotion of water awareness tours, as well as the many other services that they provide for water users.

Piaza. The only technical problem he reports happened after they switched from chlorination to ultraviolet disinfection about seven years ago. A couple years later, the maintenance people in the parks reported that solids were jamming their sprinklers and damaging the sprinkler heads. Both biofilm material and snails were found. Piaza believes that the snail larvae passed through the 200 micron screens used to filter the reused water and that they subsequently grew larger in the pipes. Sodium hypochlorite injection is being planned for that system, to ensure that residual chlorine will kill the snails.

Piaza cautions that irrigation with reused water works best on well-drained soils where rainfall is scarce. Total dissolved solids (TDS) can be high in reused water, and where TDS exceeds 600 mg/l and there is not enough natural precipitation to wash the salts down, salt buildup in the soil is a possibility. He said that the TDS is relatively low in Santa Rosa, and they have wet winters, so they have not experienced salt buildup problems.

Piaza also emphasized the importance of user education. Even in California, where water reuse has been practiced at least as much as anywhere in the nation, local groups recently successfully resisted some parts of a park irrigation project in the Bay Area. Especially on a new project, in an area where spray irrigation of ballparks has not been done before, he says, “I can’t stress enough how important educating the public is going to be. Get the public in on it from the get-go. Talk about what you’re planning to do, what recycled water is, and the steps it goes through to become recycled water.”

Elsewhere in California, Kai Dunn at the Victorville office of Lahontan Regional Water Quality Control Board mentioned that the Los Angeles County Sanitation District was irrigating “a couple hundred state or county parks” with reused water, but we were not able to obtain details on those projects from a local person.

The organization Safe Water Reuse Foundation (SWRF) lists 20 incidents of cross-connection between potable and reclaimed water supplies that they say were reported to California State Health between 1991 and 2002[3]. The incidents had anywhere from no impact (when they were discovered before any flow of reused water into potable water supplies could take place) to a potential effect on 1650 homes. The SWRF believes that this list is incomplete, because cross-connections may go unreported. We have not verified the SWRF claims with California State Health.

[3] http://www.safewaterreuse.org/incidents.html

4.2.2. Florida

The Florida Department of Environmental Protection (DEP) manages a comprehensive water reuse program with the stated objective of "encouraging and promoting reuse" (http://www.dep.state.fl.us/water/reuse/). DEP rules, contained in Chapter 62-610 of the Florida Administrative Code (F.A.C.), direct municipalities, counties, and private operators in the design, construction, and management of reclaimed water systems. In our review, we found that system managers felt the DEP's regulations were sufficiently stringent and appropriate. Thus, county or local regulations have not been widely adopted.

A 2003 state-wide inventory of reuse systems by DEP determined that 215 systems provide reclaimed water to customers for "public access reuse" (http://www.dep.state.fl.us/water/reuse/docs/App_F2003.pdf). The majority of customers are private residences (approximately 154,000) connected to reclaimed water distribution systems and using reclaimed water for landscape irrigation. A total of 427 golf courses, 486 parks, and 213 schools in Florida also irrigate with reclaimed water.

In a sampling of some of the larger systems providing reclaimed water for public access reuse, four municipalities reported very similar experiences. Interviews were conducted with personnel at the City of St. Petersburg, City of Cocoa Beach, Pinellas County Utilities, and the City of Apopka. Scott Barber of the City of Cocoa Beach reflected the thinking of each manager contacted: "We are happy with it (reclaimed water) down here in Florida" (S. Barber, personal communication, 2005).

The City of St. Petersburg Florida operates one of the oldest water reclamation systems in the United States, and it remains one of the largest reuse programs in the world (http://www.stpete.org/wwwrecla.htm). The system serves approximately 10,500 customers with a total of 36.9 million gallons per day of reclaimed wastewater for use in landscape irrigation. Sites irrigated with reclaimed wastewater include private residences, golf courses, parks, and schoolyards (including ball fields). An estimated 15-20 ball fields are spray irrigated with reclaimed water (S. Bates, personal communication, 2005). There have been no documented health impacts attributed to use of reclaimed water in St. Petersburg (B. Bates, personal communication, 2005). Reclaimed water is an integral part of the city's overall water conservation effort, significantly reducing the demand on limited potable water supplies. Another goal of the program is to limit discharge of wastewater effluent to the coastal waters of Tampa Bay.

St. Petersburg has four plants producing reclaimed water (B. Bates, personal communication, 2005). Each plant has a covered storage tank, ranging in size from 2.5 million gallons to 18 million gallons. The storage time for reclaimed water prior to distribution is generally under two days. Bates mentioned that St. Petersburg had an open storage pond at one point, but that it was disbanded after five years in use because of problems with algae and aquatic weed growth. Bates indicated that use of water from storage ponds tends to clog up the distribution and dispersal system and can result in odor problems. He suggests it is preferable to use covered storage, limit the duration of storage, and maintain a chlorine residual through the storage and distribution system.

At one of St. Petersburg four plants, there have been problems associated with high chloride concentrations in wastewater. This plant receives wastewater from a coastal community. Infiltration of saline groundwater into the sewer lines in this community is the likely source of the high chloride levels. When chloride levels in influent wastewater exceed approximately 600 mg/l, reclaimed water from the plant is not distributed (it is pumped to deep injection wells instead) to avoid possible salt accumulation in soils and damage to vegetation.

In 1981, the City of Cocoa Beach began using reclaimed water to spray irrigate golf courses. By 1985 or 1886, the City began providing reclaimed water to residences for lawn irrigation. Currently there are 1,700 residential customers (connections)—many of whom are condominium complexes or other multiple-user customers—and the City cannot satisfy the demand for reclaimed water. The schools and golf courses in Cocoa Beach spray irrigate with reclaimed water; it has been used on three or four soccer fields and another three or four baseball fields since the early 1990s with no reported adverse impacts.

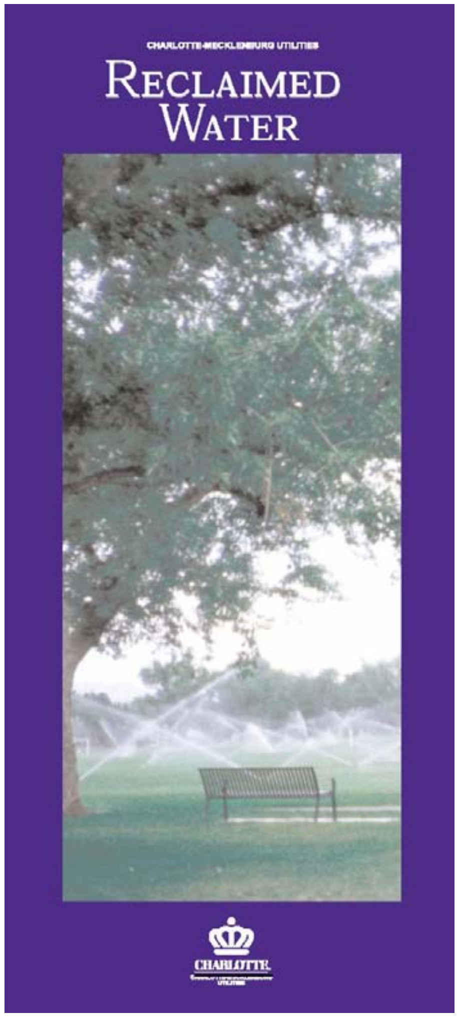
When use of reclaimed water in Cocoa Beach was expanded to private residences, there was some resistance on the part of the public to accept the practice. Scott Barber credits three factors as important in swaying public attitudes toward acceptance of irrigation with reclaimed water. The City initiated a testing program for viruses in reclaimed water and conducted many site tours to educate the public. The testing program demonstrated that virus levels in reclaimed water were non-existent or at very low (acceptable) levels. Barber credits the test results and education and outreach efforts with winning over the skeptical public. A major selling point for use of reclaimed water has been the fact that the City provides it to customers for a minimal fee of $8 a month regardless of quantity used. In the more than 20 years since the program began, there have been no documented health or environmental impacts attributed to use of reclaimed water in Cocoa Beach.

Pinellas County's Alternate Water Sources division serves approximately 12,000 customers with reclaimed water, including five or six golf courses and four or five schools (C. Powers, personal communication, 2005). When the reuse program started in the early 1970s, the utility encountered public resistance. The utility held many workshops to introduce the public to the concept of water reclamation, and gradually the public came to accept the practice. As with Cocoa Beach, demand for reclaimed water is now outstripping supply. In the more than 30 years since the program began, there have been no documented health or environmental impacts attributed to use of reclaimed water. Ms. Powers did note that reclaimed water produced by Pinellas County is not appropriate for spray irrigation of salt intolerant plants such as azaleas, which can be damaged by salt accumulation on the foliage.

The City of Apopka has had a similar experience with spray irrigation of reclaimed water. John Jreij at the City of Apopka noted that the City generates an average of 2.3 MGD of reclaimed water and, like Cocoa Beach and Pinellas County, cannot meet current demand (J. Jreij, personal communication, 2005). He estimates that 15-20 ball fields in Apopka are spray irrigated with reclaimed water. He is not aware of any adverse health or environmental impacts attributed to reclaimed water since the reuse program began in 1989. Mr. Jreij noted the importance of several state requirements for spray systems that he believes help ensure public health protection: reclaimed water pipes in the city are purple to distinguish them from potable water pipes; standard hose bibs are not allowed on the reclaimed water distribution system; and signage is installed at spray sites to notify the public. Irrigation may only occur two days a week and not between the hours of 10:00 am and 4:00 pm, practices Mr. Jreij indicated are sound irrigation practices and also limit public contact with reclaimed water.

4.2.3. North Carolina

In North Carolina, reused water has been used for spray irrigation of landscapes on a limited basis. The current regulations for reuse of wastewater are summarized in Appendix A. These regulations are less stringent about the quality of reused water, particularly with respect to fecal coliform counts, than in many other states (Hilger and Sobsey 2003). University of North Carolina Charlotte professor Helene Hilger researched regulations in other states and compared them with North Carolina's; she says that new regulations in North Carolina, more similar to California's, have been proposed by a state committee and are beginning the review process.



Charlotte-Mecklenburg utilities began with spray irrigation of reclaimed water at a golf course and the Parks and Recreation Department's facilities in 1998. The water is treated by an activated sludge facility followed by UV disinfection. There is no detention pond. Sodium hypochlorite is injected into the water at the reuse station. The reuse has temporarily been stopped because of technical problems. Plant manager Roy Perguson says that they are sorting through the technical issues and hope to get it running again, "although not next week." The issues that stopped irrigation with reused water were high turbidity and chlorine residuals. Instrumentation at the irrigation system detected high levels of turbidity or chlorine and automatically switched over to irrigation with potable water. This happened frequently enough that it was decided to disconnect the reused water until more reliably low levels of turbidity and chlorine residuals could be produced. Perguson emphasized the importance of language choice when describing reused water. When asked a question about irrigating with reused wastewater, he replied, "Let me save you a heap of heartache. We don't irrigate with wastewater. It's wastewater when it comes to my plant. When it leaves, it's reuse [pronounced with a soft s] water."

The people interviewed in Charlotte referred us to the Town of Cary for a successful example of reuse in North Carolina. Cary has been irrigating with reclaimed water since 2000 or 2001, according to John Dodson, the coordinator of the reclaimed water program at Cary Public Works & Utilities Department. The water is used on several ball fields and soccer fields. Obviously enthusiastic about the reclaimed water, Dodson reports "the people who use it love it." They have not had any technical problems, unless you count the fact that interest in the reused water has grown so quickly that they have not been able to increase the supply fast enough to meet demand. Site conditions were not a big concern, as long as the water table is not close to the surface; they have clayey soils that have worked fine for receiving reused water irrigation. He did acknowledge that the water can migrate sideways and possibly break out of a hillside in the clayey soils, but he was not concerned with that—if the water was clean enough to irrigate with, he did not see a problem in having it flow through the soil and then break out somewhere. Dodson is not aware of any public health problems associated with their irrigation with reused water.

Even though the demand for reused water in Cary has outstripped supply, Dodson says that "customer education is the hardest part: you've got to convince people that it is something they want to use." He emphasizes meetings, "physically talking with customers," as the way to introduce new customers. He holds classes and explains what reclaimed water is, to overcome the customers' initial bad perception of reclaimed water. He emphasizes that after the tertiary treatment, the difference between Cary's reused water and potable water is not visible when they are held up side by side in glass jars—and it's easy to imagine Dodson holding up the jars in a class. The water reuse system is also explained on the Town's web site (http://www.townofcary.org/depts/pwdept/reclaimhome.htm).

4.2.4. Pennsylvania

Pennsylvania has established guidelines for treated wastewater reuse and its climate is more similar to Virginia than other states where spray irrigation is common. The State of Pennsylvania's Department of Environmental Protection (PA DEP) published a guidance document titled "Manual for Land Application of Treated Sewage and Industrial Wastewater" (1997) that describes site criteria for spray irrigation sites, basic system design, wastewater pretreatment standards, site preparation, and allowable application rates. The manual is geared towards safe dispersal of secondary wastewater effluent, not toward beneficial reuse of reclaimed water.

According to Keith Bair at PA DEP, there are between 15 and 20 spray irrigation systems in Pennsylvania (K. Bair, personal communication, 2005). Most systems irrigate common green spaces in the Philadelphia area. Mr. Bair was not aware of any reuse systems specifically irrigating ballparks. There are no documented health or environmental impacts attributed to use of a spray system in Pennsylvania. In general, the State has had little trouble related to proper operation of spray irrigation systems.

The Delaware River Basin Commission and other groups support reuse projects in Pennsylvania as a means to reduce "mining" of groundwater aquifers. The majority of spray systems in Pennsylvania irrigate only at night, which Mr. Bair credits with minimizing public resistance.

Based on a general description of the proposal for the Fauquier County site, Mr. Bair indicated he thought a drip dispersal system might be more appropriate than a spray irrigation system. If feasible, the advantages of drip systems in his view are:

- Contact with reuse water is minimized.
- Concern over wind drift is eliminated.
- Public perception is more favorable.
- It is possible to disperse effluent in drip systems under conditions where use of spray is impractical, which greatly reduces necessary storage provisions. These conditions include: when ground is frozen (soil near drip lines rarely freezes), when the field is in use, even when it is raining or there is snow on the ground.
- Mr. Bair also suggested, based on experiments he has conducted, that he believes spray irrigation on disturbed construction sites is problematic. He noted that compaction occurs in site preparation, which results in a perched water table developing above a fragipan layer, even where fill soils are added post-construction.

While a drip system is potentially preferable to a spray system for the reasons Mr. Bair cites, a drip system is not believed to be feasible at the proposed site in Fauquier County.

4.2.5. South Carolina

South Carolina has between 50 and 100 spray irrigation systems applying treated wastewater in the state (B. Asbill, personal communication, 2005a). The majority of these systems irrigate golf courses, and most of the remaining spray systems are on dedicated, restricted sites. Only two systems in the state spray irrigate ball fields. One of these systems, Mount Pleasant Utilities, irrigates ball fields adjacent to their two treatment plants, neither of which has an extensive distribution system for reuse water. A manager at this system, Greg Hill, reports that the ball fields have been irrigated with secondary effluent for a period of 10 years, with no complaints or documented health or environmental impacts (G. Hill, personal communication, 2005a). Mr. Hill claims the public is receptive to these irrigation projects because the condition of the fields is very appealing. A minor portion of the utility's wastewater is directed to these spray fields, while the majority is discharged to the ocean. The treated wastewater applied does not necessarily meet the state of South Carolina's Reclaimed Water standard; the utility's permit specifies the same treatment standards for the reused wastewater as for the effluent discharged via the outfall to the ocean (G. Hill, personal communication, 2005b). According to Brian Asbill (B. Asbill, personal communication, 2005b), the permit conditions are based in part on the fact that the utility can direct use of the reclaimed water to a greater degree than utilities with extensive reclaimed water distribution systems.

On Hilton Head Island, Kelly Ferda at the South Island Public Service Department notes that application sites for reclaimed water generated by the plant include hotel landscaping, private residences, parks, ball fields, and other green spaces (K. Ferda, personal communication, 2005). This utility is the only one in the state meeting South Carolina's stringent reclaimed water standard. The utility distributes approximately five million gallons per day to customers when conditions are appropriate for irrigation. The utility has the option of discharging to a 104-acre wetland during wet weather periods, which greatly reduces the need for large storage structures for reclaimed water. The utility constructed a dual distribution system in 1983 and has since provided customers with inexpensive water for non-potable applications. An impetus for development of the reuse system was to limit saltwater intrusion on this barrier island caused by excessive pumping of groundwater. Since beginning operation, there have been no documented health or environmental impacts attributed to the reclaimed water system.

Certain management practices are critical to the success of spray irrigation systems on unrestricted urban areas. Among other practices, Ms. Ferda noted that potential human health risks should be minimized by relocating or sheltering drinking fountains and picnic tables near spray irrigation sites. She also noted that effluent ponding must be monitored and corrected where it occurs.

4.2.6. Washington

Water shortages are the primary driver behind water reclamation projects in Washington State (C. Riley, personal communication, 2005). The Department of Health reviews applications for water reuse projects involving dispersal of reclaimed water in the public way, although the primary regulatory body is the Department of Ecology. Washington State has stringent treatment standards for reclaimed water quality. All reuse water to be used on open access public areas must meet the "Class A" standards, as follows: "wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample."

There are two major water reuse systems in Washington, one in the City of Yelm and the second run by King County. The City of Yelm irrigates city parks and residential lawns with reclaimed water, and is initiating irrigation at a junior high school. King County's South Plant serves reclaimed water to a sports complex with multiple soccer and baseball fields. Irrigation of these fields has been in progress for five to seven years. Mr. Riley is aware of no health incidents stemming from the use of reclaimed water in Washington State.

5. PUBLIC CONCERNS AND INVOLVEMENT

5.1. Public Concerns Related to Spray Irrigation with Treated Wastewater

Water reuse for non-potable purposes (*e.g.*, landscape irrigation, industrial process water, toilet flushing) has been implemented across the country, but particularly in dry and drought-prone areas (like California, Arizona, Colorado, and Texas) and in areas where population and economic growth are straining water supplies (Florida and Georgia) (WERF, 2003). Surveys and case studies conducted since the 1970s have generally found that the public supports the concept of using reclaimed water, and that the public is somewhat supportive of reuse initiatives (US EPA, 2004). As concepts and options become more concrete, attitudes tend to change, and public support can wane (Bruvold, 1988).

Public concerns usually focus first on potential health impacts to the users of reclaimed water (described in Section 2.2), and secondarily on the potential environmental impacts of reclaimed water dispersal or reuse (described in Section 2.1). Concerns related to health impacts tend to be foremost when some form of potable reuse is proposed (for example, by discharging reclaimed water to a reservoir used as a drinking water source). The “yuck factor” is a major consideration in the public’s perception of wastewater reuse proposals. In recent years, large indirect potable water reuse projects have been stopped in San Antonio, Texas, San Diego, California, and in Florida due to public opposition (WERF, 2003). Public acceptance is often higher when the following conditions are met:

- The degree of human contact is minimal
- Protection of public health is clear
- Protection of the environment is a benefit of reuse
- Promotion of water conservation is a benefit of reuse
- The cost of treatment and distribution systems and technologies is reasonable
- The community has high awareness of water supply problems
- The role of reclaimed water in the overall water supply and hydrologic cycle is understood
- The perception of the quality of the reclaimed water is high
- Confidence in local management of public utilities and technologies is high (Bruvold, 1988; Lawrence, 2000; Lohman, 1984; Jeffrey, 2001; WERF, 2003; US EPA, 2004).

5.2. Guidelines for Public Education and Involvement

Effective public participation programs invite two-way communication, provide education, and ask for meaningful input as a reuse program is developed and refined. Public involvement or participation efforts generally work to identify key stakeholders and community issues at a very early stage and offer information and opportunities for input in a clear, understandable way (US EPA, 2004). The development plan currently under consideration in Fauquier County is somewhat unique, because many stakeholders (such as homeowners who will contribute wastewater to the proposed spray irrigation reuse system) cannot be directly identified. However, likely stakeholders include nearby property owners, members of the Fauquier County Parks and Recreation Department and the Water Sanitation Authority, VDEQ and VDH staff, the developer, reporters and editorial staff of local newspapers and TV stations, local watershed or environmental associations, and citizens who are potential users of the proposed park.

A one-size-fits-all model for public education and involvement will often fail because the most appropriate and effective tools and techniques will vary from case to case (WERF, 2003). What is most important is a commitment to the application of several core principles that contribute to how public confidence and perception are built and managed (or damaged and eroded) within a public decision-making process. These five principles include:

- Managing information for all
- Maintaining individual motivation and demonstrating organizational commitment
- Promoting communication and public dialog
- Ensuring fair and sound decision making and decisions
- Building and maintaining trust (WERF, 2003)

The five core principles are briefly described below.

Managing information for all means promoting communication, providing a variety of opportunities to exchange information and develop mutual understanding, and allowing and providing free access to information. Information should not be hidden from the public, but it should be presented using diverse methods to accommodate different learning styles (including written materials, seminars or workshops, images, photos, graphics, meetings, or public tours). Diverse individuals with varied needs and knowledge should have the venues and tools to listen to and learn from each other throughout the decision-making process (WERF, 2003).

Education and awareness may not result in sufficient **motivation** or **organizational commitment** to build and maintain public confidence. For many people, there needs to be more than one reason to participate in a decision making process involving water reuse. If motives are perceived as benefits rather than risks, then engagement and public dialog can contribute to building a strong relationship between the system manager and the community (WERF, 2003). A genuine commitment on the part of the system manager to engage and work with the affected public goes a long way toward producing more benefits, while a halfhearted commitment could quickly damage public confidence.

Communication and broader, cumulative **public dialog** should occur throughout a decision-making process, even beyond implementation of the chosen alternative. Expect to have to say the same thing multiple times and in multiple ways before it is understood by others. Conversely, expect to have to listen to others' messages multiple times and in multiple ways before understanding them (WERF, 2003). Keep in mind that the quality of a public dialog is an indicator of the relationship between the public and the system managers, and also reflects the public's confidence in the manager.

All participants should perceive the **decision-making process** and the decision's outcome as **fair and sound**. Sound decisions are reasoned, well thought-out, and based on accepted knowledge. Fairness relates to both the decision-making process and the outcome. Burdens and benefits of the decision should be shared fairly (WERF, 2003).

Careful attention to the previous four principles contributes to the **establishment and maintenance of public confidence and trust**. Trust can be thought of as a good friend and neighbor: friends are not made when they are needed, but if a friendship has been established with a neighbor, that neighbor will be available when needed (WERF, 2003). Get to know stakeholders during times when there is not a crisis, so that there is some trust and credibility if a crisis occurs.

5.3. Additional Resources

The federal government and several national organizations offer support and resources for communities undertaking water reuse projects.

The United States Environmental Protection Agency (US EPA) (http://www.epa.gov/water/you/intro.html) supports water reuse as one component of wider efforts to conserve and protect valuable water resources. They also published the recently updated Guidelines for Water Reuse, which presents and summarizes recommended water reuse guidelines, along with supporting information, for the benefit of water and wastewater utilities and regulatory agencies in the United States.

The WateReuse Association (http://www.watereuse.org/) is a non-profit organization whose mission is to advance the beneficial and efficient use of water resources through education, sound science, and technology using reclamation, recycling, reuse, and desalination for the benefit of their members, the public, and the environment. The Association sponsors research, conducts outreach, and works towards Federal and State support for water reuse. Members include water and wastewater utilities, Federal and state agencies, health officials, consultants, and scientists.

The Water Environment Federation (WEF) (http://www.wef.org/) is a non-profit technical and educational organization with members from varied disciplines who work toward a vision of preservation and enhancement of the global water environment. This organization focuses primarily on issues related to wastewater, biosolids, and watershed management, including support for the use of reclaimed water for non-potable purposes as a means of conserving potable water supplies. The Virginia Water Environment Association (VWEA) (http://www.vwea.org/) is a Member Association of the Water Environment Federation. One of their objectives is "the stimulation of public awareness of the relationship of water resources to the general public welfare, and the need for preservation and reuse of water resources". This organization may support the proposed reuse project in Fauquier County from the standpoint of promoting water conservation.

The American Water Works Association (AWWA) (http://www.awwa.org/) is an international nonprofit scientific and educational society dedicated to the improvement of drinking water quality and supply. The Virginia Section of the AWWA has a Water Reuse Committee that disseminates information including technological, financial, and social impacts relating to water reuse issues in the Commonwealth. The Committee Chair is Scott Smith, P.E. of Michael Baker Jr., Inc. (757-631-5430 or swsmith@mbakercorp.com).

6. SITE AND ENVIRONMENTAL CONDITIONS

The proposed project being presented to Fauquier County Parks and Recreation Department and the County Board of Supervisors is to give approximately 100 acres of a 271-acre parcel to the County for their use as a park, with the stipulation that the developer be allowed use of the site for the dispersal of treated residential wastewater using spray irrigation on the recreational ball fields. The developer would design and construct the collection, treatment, storage, and dispersal systems, and would hand over ownership to the Fauquier County Water and Sanitation Authority (WSA) for ongoing operation, maintenance, monitoring, and administration related to the system.

Figure 2: Photo looking northwest towards a portion of the 100-acre parcel, including woods in background.

The proposed use of the 100-acre portion of the site is for development of a park operated by the Fauquier County Parks and Recreation Department. The park would include several ball fields (for baseball, soccer, and football), which would receive heavy use particularly during April/May and September/October. Other possible uses of the park include a community center and a community swimming pool.

The entire parcel, called the Wampler Tract, is located west of Catlett Road (Route 28) in Warrenton, and is owned by Mr. Larry Dahl. The parcel includes rolling open hayfields and mixed woods with two existing residences: one along the main road; and a farmhouse and outbuildings located within the property. A stream named Licking Run flows through the larger tract, and is located over 900 feet south of the park site. The floodplain of Licking Run is currently being mapped, but results of the mapping effort are not yet available.

The proposed 100-acre site includes open fields and woods and is not within a floodplain (J. Kwiatkowski, personal communication, 2005); however, there are swales that drain runoff and intercepted groundwater off the property. The soils underlying the site are sedimentary-derived Triassic age materials consisting predominantly of silt loam, with some silty clay loam, loam, and clay (J. Sawyer, personal communication, 2005). The Fauquier County Soil Scientist, Jim Sawyer, developed soil maps of the property to a scale of 1"=400'. Table 6 includes a description of the soil types on the parcel, with key information on depth to bedrock, impervious layers, and seasonal high groundwater table. Seasonal high groundwater ranges from 0-6 inches below ground in the drainage swales, to no seasonal groundwater table to depth (60 inches). Surficial bedrock includes soft shales and sandstones. Bedrock depths range from 10 inches to 60 inches below ground. The predominant soil types on the site are Penn loams (no seasonal high groundwater table, 20-40 inches to bedrock), and Ashburn silt loam (18-40 inches to seasonal high groundwater table, 20-40 inches to bedrock).

Spray Irrigation of Athletic Fields Using Reclaimed Water:
A Review for Fauquier County

Table 6: Soil Characteristics on Proposed Spray Irrigation Site

			Depths (inches)				
Series #	Series Name	Slope (%)	Seasonal High Groundwater	Impervious Soils	Bedrock	Hydric Soil	Conventional System Suitability
71B	Panorama silt loam	2-7	None	None	40-60	No	Marginal
73A	Penn loam	0-2	None	None	20-40	No	Poor
73B	Penn loam	2-7	None	None	20-40	No	Poor
74B	Ashburn silt loam	2-7	18-40	30-40 (some places)	20-40	No	Poor
77B	Arcola-Nestoria complex	2-7	None	None	10-40	No	Poor
78A	Dulles silt loam	0-2	6-40	20-60 (frequently)	40-60	Yes	Not suited
78B	Dulles silt loam	2-7	6-40	20-60 (frequently)	40-60	Yes	Not suited
79A	Albano silt loam	0-2	0-6	20-40 (usually)	40-60	Yes	Not suited

Source: Fauquier County Soil Scientist, 2005.
Path: O:/Proj-04/1551-W/Report/Draft/Table06_SiteSoils2005.03.02.xls
Date/init: 02-22-05 mkc; rev 03-02-05 anm

The proposed drinking water supply for the development includes two new drilled wells, and design and construction of a municipal water distribution system for the development and park (K. Skinner, personal communication, 2005). A hydrogeologic firm is investigating locations for the community wells (K. Skinner, personal communication, 2005). There is potential near the proposed site for water supply wells with long term yields of 200-600 gallons per minute from intensely fractured zones (USGS, n.d.). However, heavy use can result in a cone of depression in the water table near these water supplies (J. Sawyer, personal communication, 2005).

The current wastewater treatment system design serves approximately 150 new single family residences, with estimated design flows of 81,000 gpd including the park (J. Kwiatkowski, personal communication, 2005). The engineering design for the wastewater treatment system is in a very early stage. The expected treatment train includes a traditional sewer collection system connected to a wastewater treatment plant (WWTP). The treatment standard is expected to be at a tertiary level but the exact type of treatment system to be built is still in the planning stage (J. Kwiatkowski, personal communication, 2005). The engineers are currently considering either an extended aeration technology or a sequencing batch reactor (SBR). Treatment plant effluent would be disinfected using ultraviolet (UV) disinfection before discharging to a holding pond. The storage pond is proposed to provide 120 days of storage (9.7 million gallons at 81,000 gpd) as required by 9 VAC 25-790-880 (L. Miller, personal communication, 2005). The water would be pumped out of the pond, treated with chlorine disinfection, and dispersed through spray irrigation nozzles placed in the ball fields.

The proposal includes site disturbance to create suitable slopes for the ball fields. A consulting firm (Soils & Environmental Services) also completed soil testing and a preliminary layout of the best sites for the ball fields for spray dispersal, but the site engineering for the park property is currently not in the scope of the civil engineer's work (K. Skinner, personal communication, 2005). It is unknown at this time how many acres of fields will be needed for the system. Commonwealth of Virginia regulations 9 VAC 25-790-880—Land Treatment specify a typical maximum annual loading depth of 36 inches (0.69 inches/acre/week) for slow rate systems to compute the field area size. Other regulations allow application rates of 0.5 inches/acre/week on poorly drained soils, and up to 2 inches/acre/week on deep, well-drained soils (Pennsylvania DEP, 1997). For design flows of 81,000 gpd, the required area at Virginia's typical maximum loading rate would be 30.2 acres.

7. CONCLUSIONS AND RECOMMENDATIONS

Treated wastewater is being reused in many parts of the United States. The sizes of these water reuse systems range from individual residential systems to publicly owned treatment works (POTW) handling millions of gallons per day (gpd). Reused water is a valuable resource with many applications. Use of reclaimed water for irrigation conserves potable water supplies, reduces wastewater discharges to surface waters, and recharges groundwater supplies, which can reduce saltwater intrusion in coastal areas. The central question considered in evaluating potential reuse applications is whether the quality of the reclaimed water is appropriate for the intended use.

Wastewater treatment standards for reuse applications vary among jurisdictions, but typically include secondary treatment, filtration, and disinfection prior to dispersal. The level of treatment relates to the specific use of the treated wastewater, the level of human contact expected, and the required buffer zones. Higher level uses such as irrigation of public lands and agricultural crops to be consumed without processing require a higher level of wastewater treatment prior to reuse than irrigation of restricted sites or forage crops and pasture, for example.

Potential risks and impacts resulting from spray irrigation on athletic fields are intimately intertwined with public concerns about water reuse systems. While public health risks from contact with wastewater effluent are real, and cases of human illness and even death have occurred from contact with poorly treated reuse water in other countries, there are currently no documented cases of illness resulting from public contact with treated reuse water in the United States. On the other hand, environmental impacts from the reuse of treated wastewater for agricultural and landscape irrigation are well documented in the United States. Accumulation of salts on vegetation and within the soil profile is likely the most common environmental impact of irrigation with reclaimed water. This and other impacts can be avoided or managed through the use of appropriate wastewater treatment technologies, irrigation system operation practices, and site drainage.

The best way to handle public opinion in a project such as the one proposed in Fauquier County is to engage the public "earnestly, early, and often". Starting a public dialog about the benefits of a new park that will serve the public twice by providing recreational opportunities and conserving water while the proposal is still in an early planning stage gives interested citizens an opportunity to participate in the park's creation and will likely build trust and ownership in the long run.

The specific proposal, if successful, will create approximately 150 residential lots and a county recreational park with a traditional sewer collection system going to a new tertiary wastewater treatment plant, storage pond, disinfection system, and spray irrigation dispersal system with design flows of approximately 81,000 gpd. The spray dispersal system would be constructed on recreational ball fields of a proposed park to be operated by Fauquier County Department of Parks and Recreation. The proposed park property does not currently have a site plan or development plan, but the County is considering a community center and a swimming pool in addition to the ball fields.

The wastewater treatment and dispersal system would be taken over by the Fauquier County Water and Sanitation Authority (WSA) for ongoing administration, operation, maintenance, and monitoring. The County Board of Supervisors would receive the 100-acre parcel in exchange for use of the ball fields for the dispersal system.

The 100-acre parcel is currently open fields and wooded areas, gently sloping in all directions although mainly to the south and east. The soils are mostly silt loams with varying depths to seasonal high groundwater table and bedrock. The site is generally high ground with some swales, which drain groundwater and water runoff off the fields. Soils analysis is currently being completed to locate the proposed fields in areas of the most favorable soils. The County Soils Scientist has visited the site and believes it to be suitable for this type of application.

The Virginia Department of Environmental Quality (DEQ) has jurisdiction over the permitting process for the design, construction, and operation of any systems larger than 40,000 gpd. The Woodbridge Regional office would be the office involved with this review and approval. The Virginia Department of Health (VDH) will likely be asked to conduct a review of the plans and specifications and assist with the review of the soils and site in relation to the ball field design, although it does not have any direct jurisdiction on this project. The VDH does have regulations allowing spray irrigation systems for individual residences, but this type of project does not trigger that regulation. The Fauquier County Parks and Recreation Department will be involved with the site plan development for the park. The Fauquier County Community Development Department will be involved with the subdivision and building permitting, plus may provide additional soil analysis support. The Fauquier County Water and Sanitation Authority (WSA) does have jurisdiction for reviewing, permitting, and inspecting this system during construction, and will take over ownership, operation, maintenance, monitoring, and administration of the utility.

7.1. Recommendations

Spray irrigation on recreational ball fields is being successfully done in many parts of the country, and with the right controls and conditions—including strong public support—it can be a viable method of water reuse.

Early agreements between the various internal stakeholders (Department of Parks and Recreation, WSA, developer) are essential. Agreements are necessary for actual parcel boundaries, ball field locations, and sizes needed for the spray dispersal area. The parties responsible for various aspects of design, permitting, construction, inspection oversight, and testing need to be designated. For example, the Parks Department needs to be involved with the overall site planning for that parcel, and should review field layouts and spray system designs. The Virginia Department of Health also needs to be involved to some extent, even if their involvement includes only informal reviews. Both DEQ and VDH staff recommended an early meeting with the internal stakeholders to work through the details of the review and approval process.

Soil conditions and site layout remain important considerations, even if the soil is not expected to provide much treatment. The water needs to be able to soak into the ground, provide the right nutrient balance to maintain healthy vegetation, and keep the soils from becoming saturated. Since the existing soils are relatively fine-grained and less permeable than sands, careful site preparation will be needed to maintain natural soil texture, or to provide an interface with fill material. A water balance and nutrient analysis should be performed, and a hydrogeologic analysis of groundwater depth and flow direction should be performed to ensure sufficient depth of unsaturated soils in the irrigation area and proper placement of groundwater monitoring wells. Ongoing soil and plant analysis will be needed to maintain ideal growing conditions. Adopting safety precautions and best management practices can minimize public exposure, including nighttime application and use of low trajectory nozzles and buffers to reduce aerosol travel.

Careful system operation and maintenance and monitoring during the first year of operation and beyond is crucial to how well the system performs, whether there are problems with field saturation, and whether the public perceives that the system is functioning and safe. Treatment reliability is of paramount importance to prevent application of inadequately treated water in the event of equipment failure or process upset. Hilger and Sobsey (2002) note that good treatment reliability may be difficult to achieve during system start-up. Problems with poor start-up lead to operator frustration and public distrust. DEQ and the WSA will both be involved throughout the project and into the future. DEQ will review monitoring and inspection reports, and can make visits to the site to ensure proper operation. As is done in Florida, the occurrence of specific pathogens including *Cryptosporidium* and *Giardia* in the reclaimed water should be monitored periodically, in addition to regular testing of indicator bacteria levels (*i.e.*, fecal coliform). Monitoring for viruses should also be considered.

Since it is very early in the design process, the use of spray fields in other areas of the park property, such as in the woods or along road rights of ways, should be evaluated. Knowing that this is the best option and location for the proposed park and spray irrigation system will help with public acceptance. An engineering analysis of several alternatives relating to treatment, storage, and dispersal technologies should be completed, along with preliminary cost estimates (including construction, total project costs, and operation, maintenance, and monitoring costs). The WSA may want to perform a financial analysis to determine the expected user rates (including the park).

The Community Development Department may consider changes to their zoning and subdivision ordinances to address spray field proposals. The WSA might also want to revise their codes to specifically address storage and spray field dispersal systems.

A comprehensive public education and outreach effort should be developed and implemented for this project to be successful. Basic guidelines were identified in this report, and references such as the 2004 US EPA Water Reuse Guidelines and the recent public participation paper published by Water Environment Research Foundation (WERF 2003) are of particular interest. Building and maintaining public acceptance for this project will be key to its success. Since this project may be the first one of its kind in the state, it could be promoted as a demonstration or model for use in other communities.

Specific considerations related to the design and operation of a spray irrigation system utilizing reclaimed water include:

- Avoidance of potable water contamination by clearly identifying reclaimed water pipes (using purple pipes or other means) to limit cross-connections, installing backflow preventers, and ensuring adequate horizontal and vertical separation between potable and nonpotable pipes.

- Avoidance of improper use of reclaimed water by the public by prohibiting or securing hose bibs.

- Installation of signage to inform the public that reclaimed water is being used.

- Minimizing potential exposure to reclaimed water by locating drinking fountains, picnic tables, and food services away from spray irrigation sites. Any ponding of reclaimed water on the ground should be detected and corrected immediately.

- Monitor salt and specific ion concentrations in reclaimed water and irrigation field soils and manage the spray field to avoid build up of these constituents, if necessary.

- Work with regulatory bodies in good faith to ensure appropriate monitoring is performed and routine inspections are conducted.

- Provide dedicated staff to operate and maintain the spray field. Recall that one of the few unsuccessful spray irrigation systems—at Bristow Manor, Prince William County, Virginia—resulted from failure to properly operate and maintain the system, which was due in part to lack of adequate staffing.

- Operate and maintain the system in conformance with an approved operations and maintenance manual. The timing of applications with respect to precipitation events and recreational use of the fields as well as appropriate resting periods should be detailed in this manual.

- Consider the potential for water quality degradation in open pond storage of reclaimed water. Several system managers contacted expressed concern regarding potential extended storage of reclaimed water in an open pond. If feasible, covered storage may be preferable to preclude biological growth. Algae and nuisance aquatic plant growth is likely to be significant in extended pond storage, which may result in clogging of irrigation systems. The microbial quality of water may deteriorate and odor problems may develop.

- A specific recommendation regarding an appropriate water quality standard is beyond the scope of this project. Refer to Table 5: Summary of Selected Guidelines and Regulations for Unrestricted Urban Reuse Water Quality for guidance. Monitoring of reclaimed water quality *as applied in the spray field* is suggested.

Presuming the above recommendations and issues are carefully addressed, Stone believes spray irrigation is a viable alternative for the proposed project, and for the county to consider for other projects.

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APPENDIX A: TABLE SUMMARIZING REUSE REGULATIONS/GUIDELINES BY STATE FOR UNRESTRICTED URBAN REUSE (US EPA, 2004)

Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
Arizona	*Class A reclaimed water:* • Secondary treatment, filtration and disinfection • Chemical feed facilities required to add coagulants or polymers if necessary to meet turbidity criterion • Turbidity - 2 NTU (24 hour average) – 5 NTU (not to exceed at any time) • Fecal coliform - none detectable in 4 of last 7 daily samples - 23/100 ml (single sample maximum) *Class B reclaimed water:* • Secondary treatment and disinfection • Fecal coliform - 200/100 ml (not to exceed in 4 of the last 7 daily samples) - 800/100 ml	• Case-by-case basis			• Application rates based on either the water allotment assigned by the Arizona Department of Water Resources (a water balance that considers consumptive use of water by the crop, turf, or landscape vegetation) or an alternative approved method			• Class A reclaimed water may be used for residential landscape irrigation, schoolground landscape irrigation, toilet and urinal flushing, fire protection systems, commercial closed-loop air conditioning systems, vehicle and equipment washing, and snowmaking • Class B reclaimed water may be used for landscape impoundment, construction uses, and street cleaning • Application methods that reasonably preclude human contact with reclaimed water will be used when irrigating

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	(single sample maximum)							
Arkansas	• Secondary treatment and disinfection	• As required by regulatory agency		• Based on water balance using divisional average annual 90 percentile rainfall	• Hydraulic - 0.5 to 4.0 in/wk • Nitrogen - percolate nitrate-nitrogen not to exceed 10 mg/l	• Required • One well upgradient • One well within site • One well down- gradient • More wells may be required on a case-by-case basis	• Determined on a case-by-case basis	
California	• Disinfected tertiary recycled water -oxidized, coagulated (not required if membrane filtration is used and/or turbidity requirements are met), filtered, disinfected • Total coliform - 2.2/100 ml (7-day median) - 23/100 ml (not to exceed in more than one sample in any 30-day period) - 240/100 ml (maximum any one sample)	• Total coliform - sampled at least once daily from the disinfected effluent • Turbidity - continuously sampled following filtration	• Warning alarms • Back-up power source • Multiple treatment units capable of treating entire flow with one unit not in operation or storage or disposal provisions • Emergency storage or disposal: short-term, 1 day; long-term, 20 days • Sufficient number of qualified personnel				• No irrigation within 50 feet of any domestic water supply well unless certain conditions are met	• Includes landscape irrigation of parks, playgrounds, schoolyards, residential lawns, and unrestricted access golf courses, as well as use in decorative fountains • Also allows reclaimed water use for toilet and urinal flushing, fire protection, construction uses, and commercial car washing

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	• Turbidity requirements for wastewater that has been coagulated and passed through natural undisturbed soils or a bed of filter media - maximum average of 2 NTU within a 24-hour period - not to exceed 5 NTU more than 5 percent of the time within a 24-hour period - maximum of 10 NTU at any time • Turbidity requirements for wastewater passed through membrane - not to exceed 0.2 NTU more than 5 percent of the time within a 24-hour period - maximum of 0.5 NTU at any time							

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
Colorado	*Landscape irrigation excluding single-family residential:* • Oxidized, filtered and disinfected • E. coli - 126/100 ml (monthly average) - 235/100 ml (single sample maximum in any calendar month) • Turbidity - not to exceed 3 NTU (monthly average) - not to exceed 5 NTU in more than 5 percent of the individual analytical results (any calendar month) *Single-family residential:* • Oxidized, coagulated, clarified, filtered, and disinfected • Total coliform - 2.2/100 ml (7-day median)	*Treaters:* • Quality of reclaimed domestic wastewater produced and delivered at the point of compliance *Applicators:* • Total volume of reclaimed domestic wastewater applied per year or season • The maximum monthly volume applied • Each location with the associated acreage where reclaimed domestic wastewater was applied			• Application rates shall protect surface and groundwater quality and irrigation shall be controlled to minimize ponding		*Landscape irrigation excluding single-family residential:* • No impoundment or irrigation of reclaimed water within 100 feet of any well used for domestic supply unless, in the case of impoundment, it is lined with a synthetic material with a permeability of 10^{-6} cm/sec or less *Single-family residential:* • No irrigation of reclaimed water within 500 feet of any domestic supply well • No irrigation of reclaimed water within 100 feet of any irrigation well	

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	- 23/100 ml (any sample)							
Delaware	• Advanced treatment using oxidation, clarification, coagulation, flocculation, filtration, and disinfection • 10 mg/l BOD_5 • 10 mg/l TSS • Turbidity not to exceed 5 NTU • Fecal coliform - 20/100 ml	• Continuous on-line monitoring for turbidity before application of the disinfectant • Continuous on-line monitoring of residual disinfection concentrations • Parameters which may require monitoring include volume of water applied to spray fields, BOD, suspended solids, fecal coliform bacteria, pH, COD, TOC, ammonia nitrogen, nitrate nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride, Na, K, Ca, Mg, metals, and priority pollutants • Parameters		• Storage provisions required either as a separate facility or incorporated into the pretreatment system • Minimum 15 days storage required unless other measures for controlling flow are demonstrated • Must determine operational, wet weather, and water balance storage requirements • Separate off-line system for storage of reject wastewater with a minimum capacity equal to 2 days average daily design flow required	• Maximum design wastewater loadings limited to 2.5 in/wk • Maximum instantaneous wastewater application rates limited to 0.25 in/hour • Design wastewater loading must be determined as a function of precipitation, evapotrans-piration, design percolation rate, nitrogen loading and other constituent loading limitations, groundwater and drainage conditions, and average and peak design wastewater flows and seasonal fluctuations	• Required • One well upgradient of site or otherwise outside the influence of the site for background monitoring • One well within wetted field area of each drainage basin intersected by site • Two wells downgradient in each drainage basin intersected by site • One well upgradient and One well downgradient of the pond treatment and storage facilities in each drainage basin intersected by site • May require measurement of depth to groundwater,	• Determined on a case-by-case basis	• Regulations pertain to sites unlimited to public access

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
		and sampling frequency determined on case-by-case basis				pH, COD, TOC, nitrate nitrogen, total phosphorus, electrical conductivity, chloride, fecal coliform bacteria, metals, and priority pollutants • Parameters and sampling frequency determined on a case-by-case basis		
Florida	• Secondary treatment with filtration and high-level disinfection • Chemical feed facilities to be provided • 20 mg/l $CBOD_5$ (annual average) • 5 mg/l TSS (single sample) to be achieved prior to disinfection • Total chlorine residual of at least 1 mg/l after a minimum	• Parameters to be monitored and sampling frequency to be identified in wastewater facility permit • Minimum schedule for sampling and testing based on system capacity established for flow, pH, chlorine residual, dissolved oxygen, suspended solids, $CBOD_5$, nutrients, and	• Class I reliability - requires multiple or back-up treatment units and a secondary power source • Minimum reject storage capacity equal to 1-day flow at the average daily design flow of the treatment plant or the average daily permitted flow of the reuse system, whichever is	• At a minimum, system storage capacity shall be the volume equal to 3 times the portion of the average daily flow for which no alternative reuse or disposal system is permitted • Water balance required with volume of storage based on a 10-year recurrence interval and a minimum of 20	• Site specific • Design hydraulic loading rate - maximum annual average of 2 in/wk is recommended • Based on nutrient and water balance assessments	• Required • One upgradient well located as close as possible to the site without being affected by the site's discharge (background well) • One well at the edge of the zone of discharge down-gradient of the site (compliance well) • One well downgradient	• 75 feet to potable water supply wells • 75 feet from reclaimed water transmission facility to public water supply well • Low trajectory nozzles required within 100 feet of outdoor public eating, drinking, and bathing facilities • 100 feet from indoor aesthetic	• Includes use of reclaimed water for irrigation of residential lawns, golf courses, cemeteries, parks, playgrounds, schoolyards, highway medians, and other public access areas • Also includes use of reclaimed water for toilet flushing, fire protection, construction

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	acceptable contact time of 15 minutes at peak hourly flow • Fecal coliform - over 30 day period, 75 percent of samples below detection limits - 25/100 ml (single sample) • pH 6 - 8.5 • Limitations to be met after disinfection	fecal coliform • Continuous on-line monitoring of turbidity prior to disinfection • Continuous on-line monitoring of total chlorine residual or residual concentrations of other disinfectants • Monitoring for *Giardia* and *Cryptosporidium* based on treatment plant capacity - ≥ 1 mgd, sampling one time during each 2-year period - < 1 mgd, sampling one time during each 5-year period - samples to be taken immediately following disinfection process • Primary and secondary drinking water standards to	less • Minimum system size of 0.1 mgd (not required for toilet flushing and fire protection uses) • Staffing - 24 hrs/day, 7 days/wk or 6 hrs/day, 7 days/wk with diversion of reclaimed water to reuse system only during periods of operator presence	years of climatic data • Not required if alternative system is incorporated into the system design to ensure continuous facility operation • Existing or proposed lakes or ponds (such as golf course ponds) are appropriate for storage if it will not impair the ability of the lakes or ponds to function as a stormwater management system • Aquifer storage and recovery allowed as provision of storage		from the site and within the zone of discharge (intermediate well) • One well located adjacent to unlined storage ponds or lakes • Other wells may be required depending on site-specific criteria • Quarterly monitoring required for water level, nitrate, total dissolved solids, arsenic, cadmium, chloride, chromium, lead, fecal coliform, pH, and sulfate • Monitoring may be required for additional parameters based on site-specific conditions and groundwater quality	features using reclaimed water to adjacent indoor public eating and drinking facilities • 200 feet from unlined storage ponds to potable water supply wells	dust control, vehicle washing and aesthetic purposes • Tank trucks can be used to apply reclaimed water if requirements are met • Cross-connection control and inspection program required

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
		be monitored by facilities ≥ 100,000 gpd				quality		
Georgia	• Secondary treatment followed by coagulation, filtration, and disinfection • 5 mg/l BOD • 5 mg/l TSS • Fecal coliform - 23/100 ml (monthly average) - 100/100 ml (maximum any sample) • pH 6 - 9 • Turbidity not to exceed 3 NTU prior to disinfection • Detectable disinfectant residual at the delivery point	• Continuous turbidity monitoring prior to disinfection • Weekly sampling for TSS and BOD • Daily monitoring for fecal coliform • Daily monitoring for pH • Detectable disinfection residual monitoring	• Multiple process units • Ability to isolate and bypass all process units • System must be capable of treating peak flows with the largest unit out of service • Equalization may be required • Back-up power supply • Alarms to warn of loss of power supply, failure of pumping systems, failure of disinfection systems, or turbidity greater than 3 NTU	• Reject water storage equal to at least 3 days of flow at the average daily design flow • One of the following options must be in place to account for wet weather periods - sufficient storage onsite or at the customer's location to handle the flows until irrigation can be resumed - additional land set aside that can be irrigated without causing harm to the cover crop - obtain NPDES permit for all or part of the flow			• Determined on a case-by-case basis	
Hawaii	*R-1 water:*	• Daily flow	• Multiple or	• 20 days	• Design	• Required	*R-1 water:*	• R-1 water can

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	• Oxidized, filtered, and disinfected • Fecal coliform – 2.2/100 ml (7-day median) - 23/100 ml (not to exceed in more than one sample in any 30-day period) - 200/100 ml (maximum any one sample) • Inactivation and/or removal of 99.999 percent of the plaque-forming units of F-specific bacteriophage MS2, or polio virus • Effluent turbidity not to exceed 2 NTU • Chemical pretreatment facilities required in all cases where granular media filtration is used; not required for facilities using membrane filtration	monitoring • Continuous turbidity monitoring prior to and after filtration process • Continuous measuring and recording of chlorine residual • Daily monitoring of fecal coliform • Weekly monitoring of BOD_5 and suspended solids	standby units required with sufficient capacity to enable effective operation with any one unit out of service • Alarm devices required for loss of power, high water levels, failure of pumps or blowers, high head loss on filters, high effluent turbidity, loss of coagulant or polymer feed, and loss of chlorine residual • Standby power source required for treatment plant and distribution pump stations	storage required unless it can be demonstrated that another time period is adequate or that no storage is necessary • Storage requirements based on water balance using at least a 30-year record • Reject storage required with a volume equal to 1 day of flow at the average daily design flow • Emergency system storage not required where an alternate effluent disposal system has been approved	application rate determined by water balance	• Groundwater monitoring system may consist of a number of lysimeters and/or monitoring wells depending on site size, site characteristics, location, method of discharge, and other appropriate considerations • One well upgradient and two wells downgradient for project sites 500 acres or more • One well within the wetted field area for each project whose surface area is greater than or equal to 1,500 acres • One lysimeter per 200 acres • One lysimeter for project sites that have greater than 40 but less than	• Minimum of 50 feet to drinking water supply well • Outer edge of impoundment at least 100 feet from any drinking water supply well *R-2 water:* • For spray irrigation applications, 500 feet to residence property or a place where public exposure could be similar to that at a park, elementary school yard or athletic field • Minimum of 100 feet to any drinking water supply well • Outer edge of impoundment at least 300 feet from any drinking water supply well	be used for spray Irrigation of golf courses, parks, elementary schoolyards, athletic fields, landscapes around some residential property, roadside and median landscapes, landscape impoundments with decorative fountain, and decorative fountains • R-1 water can also be used for flushing toilets and urinals, fire fighting and washing yards, lots and sidewalks • R-2 water can be used as source of supply for landscape impoundments without decorative fountain and construction uses

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	• Theoretical chlorine contact time of 120 minutes and actual modal contact time of 90 minutes throughout which the chlorine residual is 5 mg/l *R-2 water:* • Oxidized and disinfected • Fecal coliform – 23/100 ml (7-day median) - 200/100 ml (not to exceed in more than one sample in any 30-day period) • Theoretical chlorine contact time of 15 minutes and actual modal contact time of 10 minutes throughout which the chlorine residual is 0.5 mg/l					200 acres • Additional lysimeters may be necessary to address concerns of public health or environmental protection as related to variable characteristics of the subsurface or of the operations of the project		• If alternative application methods are used, such as subsurface, drip or surface irrigation, a lesser quality reclaimed water may be suitable • R-2 water used in spray irrigation will be performed during periods when the area is closed to the public and the public is absent from the area, and end at least 1 hour before the area is open to the public • Subsurface irrigation may be performed at any time
Idaho	• Oxidized,							• Includes

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	coagulated, clarified, filtered, and disinfected • Total coliform - 2.2/100 ml (7-day median)							irrigation of parks, playgrounds, schoolyards and other areas where children are more likely to have access or exposure • Irrigation to be accomplished during periods of non-use
Illinois	• Two-cell lagoon system with tertiary sand filtration and disinfection or mechanical secondary treatment with disinfection			• Minimum storage capacity equal to at least 150 days of wastewater at design average flow except in southern Illinois areas where a minimum of 120 days of storage capacity to be provided • Storage can be determined based on a rational design that must include capacity for the wettest year with a 20-year	• Based on the limiting characteristic of the treated wastewater and the site • Balances must be calculated and submitted for water, nitrogen, phosphorus, and BOD	• Required • One well upgradient for determining background concentrations • Two wells downgradient in the dominant direction of groundwater movement • Wells between each potable water well and the application area if within 1,000 feet • Monitoring of nitrates, ammonia nitrogen, chlorides, sulfates, pH, total dissolved	• 200 feet to residential lot lines	

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
				return frequency		solids, phosphate, and coliform bacteria		
Indiana	• Secondary treatment and disinfection • 10 mg/l BOD_5 • 5 mg/l TSS prior to disinfection (24 hour average) • Fecal coliform - no detectable fecal coliform (7-day median) – 14/100 ml (single sample) • pH 6 - 9 • Total chlorine residual after a minimum contact time of 30 minutes at least 1 mg/l (if chlorination is used for disinfection)	• Daily monitoring of TSS, coliform, and chlorine residual • Weekly monitoring of BOD and pH • Monthly monitoring of total nitrogen, ammonium nitrogen, nitrate nitrogen, phosphorus, and potassium • Annual monitoring of arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc	• Alternate power source required	• Minimum of 90 days effective storage capacity required	• Maximum hydraulic loading rate of 2 in/week		• 200 feet to potable water supply wells or drinking water springs • 300 feet to any waters of the state • 300 feet to any residence	• Pertains to land with a high potential for public exposure
Kansas	• Secondary treatment with filtration and disinfection for irrigation of areas with a high probability of body contact			• Storage provided to retain a minimum of 90 days average dry weather flow when no discharge to surface water is available	• Maximum daily application rate of 3 in/ac/day • Maximum annual application rate of 40 in/acre • Based on soil and crop moisture	• Site specific • May be required	• None required	• Projected uses include irrigation of golf courses or public parks with a low probability of body contact • Public access prohibited

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
					and/or nutrient requirements of selected crop			during and 8 hours after irrigation
Massachusetts	*Toilet flushing:* • Secondary treatment with filtration (possibly) and disinfection • pH 6 - 9 • 30 mg/l BOD_5 • Turbidity - 5 NTU (not to exceed at any time) • Fecal coliform - 100/100 ml (single sample) • 10 mg/l TSS • 10 mg/l total nitrogen • Class I groundwater permit standards (SDWA Drinking Water Standards)	*Toilet flushing:* • pH - weekly or daily • BOD - weekly • Turbidity - continuous monitoring prior to disinfection • Fecal coliform -once per week • Disinfection UV intensity - daily or chlorine residual - daily • TSS - weekly • Nitrogen - twice per month • Permit standards - variable testing requirements	• EPA Class I Reliability standards may be required • Two independent and separate sources of power • Unit redundancy • Additional storage	• Immediate, permitted discharge alternatives are required for emergency situations and for non-growing season disposal				• The use of reclaimed water for toilet flushing is allowed at commercial facilities where public access to the plumbing is not allowed
Montana	• Oxidized, clarified, coagulated, filtered, and disinfected • Fecal coliform - 2.2/100 ml (7-day median) - 23/100 ml (single sample) • Turbidity	• Effluent to be monitored on a regular basis to show the biochemical and bacteriological quality of the applied wastewater • Monitoring			• Nitrogen and hydraulic loadings determined based on methods in EPA Manual 625/1-81-013 • Hydraulic loading must be based on	• Determined on a case-by-case basis • Consideration is given to groundwater characteristics, past practices, depth to groundwater, cropping	• 100 feet to any water supply well • Distance to surface water determined on a case-by-case basis based on quality of effluent and the level of	• Includes landscape irrigation of parks, playgrounds, schoolyards, unrestricted golf courses, and other areas where the public has

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State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	- 2 NTU (average) - 5 NTU (not to exceed more than 5 percent of the time during any 24-hour period)	frequency to be determined on a case-by-case basis			the wettest year in ten years	practices, etc.	disinfection	similar access or exposure
Nevada	• At a minimum, secondary treatment with disinfection • 30 mg/l BOD_5 • Fecal coliform - 2.2/100 ml (30-day geometric mean) - 23/100 ml (maximum daily number)						• None required	• Uses include irrigation of cemeteries, golf courses, greenbelts, parks, playgrounds, or commercial or residential lawns
New Jersey	• Fecal Coliform - 2.2/100 ml (7-day median) - 14/100 ml (maximum any one sample) • Minimum chlorine residual - 1.0 mg/l after 15-minute contact at peak hourly flow • Alternative methods of disinfection, such as UV and ozone, may be	• Continuous on-line monitoring of chlorine residual produced oxidant at the compliance monitoring point • For spray irrigation, chlorination levels for disinfection should be continually evaluated to ensure		• Not required when another permitted reuse system or effluent disposal system is incorporated into the system design • If system storage ponds are used, they do not have to be lined • Reject storage ponds shall be lined or sealed to prevent	• Hydraulic loading rate - maximum annual average of 2 in/wk but may be increased based on a site-specific evaluation • The spray irrigation of reclaimed water shall not produce surface runoff or ponding		• 75 feet to potable water supply wells that are existing or have been approved for construction • 75 feet provided from a reclaimed water transmission facility to all potable water supply wells • 100 feet from outdoor public eating,	• Secondary treatment, for the purpose of the manual, refers to the existing treatment requirements in the NJPDES permit, not including the additional reclaimed water for beneficial reuse treatment requirements • A chlorine

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	approved • TSS not to exceed 5 mg/l before disinfection • Total nitrogen - 10 mg/l but may be less stringent if higher limit is still protective of environment • Secondary • Filtration • Chemical addition prior to filtration may be necessary	chlorine residual levels do not adversely impact vegetation • Continuous monitoring for turbidity before disinfection is required • Operating protocol required • User/Supplier Agreement • Annual usage report		measurable seepage • Existing or proposed ponds (such as golf course ponds) are appropriate for storage of reuse water if the ability of the ponds to function as stormwater management systems is not impaired			drinking, and bathing facilities • 100 feet between indoor aesthetic features and adjacent indoor public eating and drinking facilities when in the same room or building	residual of 0.5 mg/l or greater is recommended to reduce odors, slime, and bacterial re-growth
New Mexico	• Adequately treated and disinfected • Fecal coliform - 100/100 ml	• Fecal coliform sample taken at point of diversion to irrigation						• Includes irrigation of parks, playgrounds, schoolyards, golf courses, cemeteries, and other areas where the public has similar access or exposure
North Carolina	• Tertiary quality effluent (filtered or equivalent) • TSS - 5 mg/l (monthly average) - 10 mg/l (daily maximum)	• Continuous on-line monitoring and recording for turbidity or particle count and flow prior to discharge	• All essential treatment units to be provided in duplicate • Five-day side-stream detention pond required for effluent exceeding	• Determined using a mass water balance based upon a recent 25-year period using monthly average precipitation data, potential	• Site specific • Application rate may take both the maximum soil absorption and water needs of the receiving crop into consideration		• 100 feet to any surface waters classified SA, including wetlands • 25 feet to any surface water not classified SA, including wetlands and	• Uses include irrigation of residential lawns, golf courses, parks, school grounds, industrial or commercial site grounds,

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	• Fecal coliform - 14/100 ml (monthly geometric mean) - 25/100 ml (daily maximum) • BOD_5 - 10 mg/l (monthly average) - 15 mg/l (daily maximum) • NH_3 - 4 mg/l (monthly average) - 6 mg/l (daily maximum) • Turbidity not to exceed 10 NTU at any time		turbidity or fecal coliform limits • Automatically activated standby power source to be provided • Certified 24 hours/day operator with a grade level equivalent to or greater than the facility classification	evapotrans-piration data, and soil drainage data • No storage facilities required if it can be demonstrated that other permitted disposal options are available			any swimming pool • 100 feet to any water supply well • 10 feet to any nonpotable well	landscape areas, highway medians, and roadways • Can also be used for aesthetic purposes such as decorative ponds or fountains, dust control, soil compaction, street cleaning, vehicle washing, urinal and toilet flushing, or fire protection in sprinkler systems located in commercial or industrial facilities
North Dakota	• At a minimum, secondary treatment with chlorination • 25 mg/l BOD_5 • 30 mg/l TSS • Fecal coliform - 200/100 ml • Chlorine residual of at least 0.1 mg/l	• BOD_5, TSS, and fecal coliform monitoring once every 2 weeks • Daily monitoring of chlorine residual at the point of use farthest from the treatment plant						• Use applies to irrigation of public property such as parks and golf courses • Signs must be posted in visible areas during irrigation and for 2 hours after irrigation is completed
Ohio	• Biological	*Large system*		• Operational	• Determined by	• Monitoring	• 100 feet to	• Includes parks,

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	treatment and disinfection • 25 mg/l CBOD$_5$ • Fecal coliform (30-day average) - 23/100 ml with no public access buffer area or night application • Limits for metals	*monitoring (150,000 to 500,000 gpd):* • Twice weekly for CBOD$_5$, total coliform (when irrigating) and storage volume • Monthly monitoring for total inorganic nitrogen • Daily monitoring for flow *Small system monitoring (<150,000 gpd):* • Weekly monitoring of CBOD$_5$, total coliform (when irrigating) and storage volume • Daily monitoring of flow		storage of 4 times the daily design flow needed • Storage provisions for at least 130 days of design average flow needed for periods when irrigation is not recommended • Actual storage requirements determined by performing water balance • Permits can be obtained for stream discharge during winter and times of high stream flow to reduce storage needs	calculating a water and nutrient balance	wells upgradient and downgradient of large irrigation systems • Monitoring wells should be sampled at the beginning and the end of the irrigation season	private water well • 300 feet to community water well • 100 feet to sink hole • 50 feet to drainage way • 50 feet to surface water • 100 feet to road right-of-way without windbreak using spray irrigation • 10 feet to road right-of-way with windbreak or with flood irrigation • 50 feet to property line	golf courses, lawns, highway medians, and playing fields
Oregon	*Parks, playgrounds, schoolyards, and golf courses with contiguous residences:* • Level IV - biological treatment, clarification,	*Parks, playgrounds, schoolyards, and golf courses with contiguous residences:* • Total coliform sampling - one time a day	• Standby power with capacity to fully operate all essential treatment processes • Redundant treatment facilities and monitoring				*Parks, playgrounds, schoolyards, and golf courses with contiguous residences:* • None required *Landscape impoundments and construction*	• No direct public contact is allowed during the irrigation cycle

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates [1]	Groundwater Monitoring [1]	Setback Distances [1] [2]	Other
	coagulation, filtration, and disinfection • Total coliform - 2.2/100 ml (7-day median) - 23/100 ml (maximum any sample) • Turbidity - 2 NTU (24-hour mean) - 5 NTU (5 percent of time during a 24-hour period) *Landscape impoundments and construction use:* • Level II - biological treatment and disinfection • Total coliform - 240/100 ml (2 consecutive samples) - 23/100 ml (7-day median)	• Turbidity - hourly *Landscape impoundments and construction use:* • Total coliform sampling - once a week	equipment to meet required levels of treatment • Alarm devices to provide warning of loss of power and/or failure of process equipment				*use:* • 10-foot buffer with surface irrigation • 70-foot buffer with spray irrigation • No spray irrigation within 100 feet of drinking fountains or food preparation areas	
South Carolina	• Advanced wastewater treatment • BOD_5 and TSS - 5 mg/l (monthly average) - 7.5 mg/l	• Minimum of one fecal or total coliform presence/ absence measurement daily • Nitrate		• Storage facilities are not required to be lined • Covered storage systems or other	• Hydraulic - maximum of 0.5 - 2 in/wk depending on depth to groundwater • A nitrate to nitrogen	• May be required	• None required	• Applies to application of reclaimed water in areas with a high potential for contact • Includes

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	(weekly average) • Turbidity - 1 NTU (monthly average) - 5 NTU (not to exceed based on an average for 2 consecutive days) • Total coliform - similar to standards in State Primary Regulations - for a system that collects at least 40 samples per month, if no more than 5 percent are total coliform-positive, the system will be in compliance with the MCL for total coliform • Total chlorine residual limits based on site conditions and distribution system design	monitoring required		alternative methods may be required to maintain effluent quality prior to distribution	loading balance may be required • Application rates in excess of 2 in/wk may be approved			residential irrigation systems, multifamily irrigation systems, commercial irrigation systems in common residential areas, public parks, and open spaces
South Dakota	• Secondary treatment and disinfection			• Minimum of 210 days capacity	• Maximum application rate limited to	• Shallow wells in all directions of major		

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	• Total coliform - 200/100 ml (geometric mean)			without consideration for evaporation	2 in/acre/wk or a total of 24 in/acre/yr	groundwater flow from site and no more than 200 feet outside of the site perimeter, spaced no more than 500 feet apart, and extending into the groundwater table • Shallow wells within the site are also recommended		
Tennessee	• Biological treatment • Additional treatment requirements are determined on a case-by-case basis • Disinfection required • 30 mg/l BOD_5 and TSS (monthly average) • Fecal coliform - 200/100 ml	• Site specific		• Storage requirements determined by either of two methods 1) use of water balance calculations or, 2) use of a computer program that was developed based upon an extensive NOAA study of climatic variations throughout the United States	• Nitrogen - percolate nitrate-nitrogen not to exceed 10 mg/l • Hydraulic - based on water balance using 5-year return monthly precipitation	• Required	*Surface Irrigation:* • 100 feet to site boundary • 50 feet to on site streams, ponds, and roads *Spray Irrigation:* [1] Open Fields • 300 feet to site boundary • 150 feet to on site streams, ponds, and roads [2] Forested • 150 feet to site boundary • 75 feet to on site streams, ponds, and roads	• Pertains to irrigation of parks, green areas, and other public or private land where public use occurs or is expected to occur
Texas	• Type I	• Sampling and			• Based on			• Type I

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	reclaimed water *Reclaimed water on a 30-day average to have a quality of:* • 5 mg/l BOD_5 or $CBOD_5$ • 10 mg/l for landscape impoundment) • Turbidity - 3 NTU • Fecal coliform - 20/100 ml (geometric mean) - 75/100 ml (not to exceed in any sample)	analysis twice per week for BOD_5 or $CBOD_5$, turbidity, and fecal coliform • Periodic fecal coliform sampling in the reclaimed water distribution system may be necessary			water balance			reclaimed water use defined as use of reclaimed water where contact between humans and the reclaimed water is likely • Uses include residential irrigation, irrigation of public parks, golf courses with unrestricted public access, schoolyards or athletic fields, fire protection, toilet flushing, and other uses
Utah	• Type I treated wastewater - secondary treatment with filtration and disinfection • 10 mg/l BOD (monthly average) • Turbidity prior to disinfection - not to exceed 2 NTU (daily average) - not to exceed 5 NTU at any	• Daily composite sampling required for BOD • Continuous turbidity monitoring prior to disinfection • Daily monitoring of fecal coliform • Continuous total residual chlorine	• Alternative disposal option or diversion to storage required if turbidity or chlorine residual requirements not met				• 50 feet to any potable water well • Impoundments at least 500 feet from any potable water well	• Uses allowed where human exposure is likely include residential irrigation, non-residential landscape irrigation, golf course irrigation, toilet flushing, fire protection, and other uses • For residential landscape

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	time • Fecal coliform - none detected (weekly median as determined from daily grab samples) - 14/100 ml (not to exceed in any sample) • 1.0 mg/l total residual chlorine after 30 minutes contact time at peak flow • pH 6 - 9	monitoring • pH monitored continuously or by daily grab samples						irrigation at individual homes, additional quality control restrictions may be required
Washington	*Landscape irrigation, decorative fountains, street cleaning, fire protection, and toilet flushing:* • Class A - oxidized, coagulated, filtered, and disinfected • Total coliform - 2.2/100 ml (7-day mean) - 23/100 ml (single sample) *Landscape impoundment and construction uses:*	• BOD – 24-hour composite samples collected at least weekly • TSS – 24-hour composite samples collected at least daily • Total coliform and dissolved oxygen - grab samples collected at least daily • Continuous on-line monitoring of turbidity	• Warning alarms independent of normal power supply • Back-up power source • Emergency storage: short-term, 1 day; long-term, 20 days • Multiple treatment units or storage or disposal options • Qualified personnel available or on	• Storage required when no approved alternative disposal system exists • Storage volume established by determining storage period required for duration of a 10-year storm, using a minimum of 20 years of climatic data • At a minimum, system storage capacity	• Hydraulic loading rate to be determined based on a detailed water balance analysis	• May be required • Monitoring program will be based on reclaimed water quality and quantity, site specific soil and hydrogeologic characteristics, and other considerations	• 50 feet to any potable water supply well • Unlined impoundments - 500 feet between perimeter and any potable water supply well • Lined impoundments - 100 feet between perimeter and any potable water supply well	• Uses include irrigation of open access areas (such as golf courses, parks, playgrounds, schoolyards, residential landscapes, or other areas where the public has similar access or exposure to the reclaimed water) and use in decorative fountains and landscape impoundments

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
	• Class C - oxidized and disinfected • Total coliform - 23/100 ml (7-day mean) - 240/100 ml (single sample) *General compliance requirements:* • 30 mg/l BOD and TSS (monthly mean) • Turbidity - 2 NTU (monthly) - 5 NTU (not to exceed at any time) • Minimum chlorine residual of 1 mg/l after a contact time of 30 minutes		call at all times the irrigation system is operating	should be the volume equal to 3 times that portion of the average daily flow for which no alternative reuse or disposal system is permitted				• Also includes use for street cleaning, construction, fire protection in hydrants or sprinkler systems, toilet flushing in commercial or industrial facilities and in apartments and condos where the residents do not have access to the plumbing system
Wyoming	• Minimum of Class A wastewater - advanced treatment and/or secondary treatment and disinfection • Fecal coliform - 2.2/100 ml or less	• Treated wastewater to be analyzed for fecal coliform, nitrate as N, ammonia as N, and pH at a minimum • Monitoring frequency - once per month for	• Multiple units and equipment • Alternative power sources • Alarm systems and instrumentation • Operator certification and standby capability • Bypass and	• Emergency storage	• Will be applied for the purpose of beneficial reuse and will not exceed the irrigation demand of the vegetation at the site • Not to be applied at a rate greater than the		• 30 feet to adjacent property lines • 30 feet to all surface waters • 100-feet to all potable water supply wells • 100-foot buffer zone around spray site	• Pertains to land with a high potential for public exposure

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Table A-1. Unrestricted Urban Reuse

State	Reclaimed Water Quality and Treatment Requirements	Reclaimed Water Monitoring Requirements	Treatment Facility Reliability	Storage Requirements	Loading Rates (1)	Groundwater Monitoring (1)	Setback Distances (1) (2)	Other
		lagoon systems - once per week for mechanical systems • Frequency specified in NPDES permit required if more frequent	dewatering capability • Emergency storage		agronomic rate for the vegetation at the site • Will be applied in a manner and time that will not cause any surface runoff or contamination of a groundwater aquifer			

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APPENDIX B: IRVING RANCH WATER DISTRICT RECLAIMED WATER QUALITY REPORT FOR 2000

IRWD

Irvine Ranch Water District

Reclaimed Water Quality Report

A report on reclaimed water quality for calendar year 2000

Irvine Ranch Water District Reclaimed Water Use At A Glance

The primary uses for IRWD reclaimed water are:

- Landscape irrigation (parks, golf courses, school playfields, greenbelts, etc.)
- Agricultural irrigation
- Front and back yard landscape irrigation for some estate-sized properties
- Industrial/commercial uses, such as carpet dyeing. Cooling tower applications are expected in the near future.
- Toilet flushing in some dual-plumbed commercial buildings

Reclaimed Water Statistics for Calendar Year 2000

- 2,818 landscape meters
- 5,653 acres of landscape use
- 44 agricultural meters
- 1,087 acres of agricultural use
- 315 miles of reclaimed water pipelines, the most extensive distribution system in California and one of the largest in the U.S.
- Total reclaimed water use during 2000 was 19,284 acre-feet.
- Reclaimed water now makes up over 20 percent of overall water used within the IRWD service area.
- The Michelson Water Reclamation Plant capacity is 15 million gallons per day (mgd). The Los Alisos Water Reclamation Plant can produce 5.5 mgd.
- A total of 225 new reclaimed meters were added to the distribution system during 2000.

San Joaquin Reservoir Would Improve Seasonal Reclaimed Water Storage

Irvine Ranch Water District (IRWD) is moving ahead with plans to convert the now-empty San Joaquin Reservoir into a facility to provide increased seasonal storage of reclaimed water.

This plan would save energy, protect Upper Newport Bay, provide reclaimed water service to expanded areas, and restore a water view to surrounding homeowners.

The reservoir, located between Newport Beach and Newport Coast, is an open reservoir that was built in 1966 to provide drinking water to customers along a 35-mile area from Huntington Beach to Dana Point. Since more stringent water quality regulations now control the storage of treated drinking water in an open reservoir, San Joaquin has not been used for that purpose since 1994 when it was drained. Metropolitan Water District of Southern

(continued on page 2)

Merger with Los Alisos Water District Expands Reclaimed Water System

On Dec. 31, 2000 Irvine Ranch Water District merged with Los Alisos Water District and began serving additional customers in Lake Forest.

The Los Alisos Water Reclamation Plant, built in 1964, currently produces tertiary-treated reclaimed water to serve 194 landscape irrigation and agricultural customers. The Los Alisos facilities are a welcome addition to IRWD's extensive reclaimed water system. Data from that system will be included in next year's report.

To our new customers: Welcome!

Questions & Answers

By reading this report, you can learn more about your local reclaimed water supply and the important steps we take to ensure its quality. Here are answers to some commonly asked questions about reclaimed water:

Is reclaimed water safe?

Yes. Reclaimed water supplied by Irvine Ranch Water District meets the stringent requirements set by the State Department of Health Services under Title 22 of the California Code of Regulations. The reclaimed water produced by IRWD is of such high quality that it has an unrestricted use permit, which means it can be used for everything but drinking. Thousands of tests are performed each year to ensure water quality. See the tables inside this report for a comprehensive summary of test results.

My dog recently drank reclaimed water from a sprinkler at the park. Is this harmful?

No. As indicated above, the reclaimed water produced by IRWD must meet very high standards. While it is not intended for drinking by people or pets, an animal which ingests reclaimed water will not be harmed. In addition to the unrestricted use permit from the State of California Dept. of Health Services (DOHS), IRWD's reclaimed water meets the DOHS recreation-1 standards. This means that the water is of such high quality it could be used to fill swimming pools. While our reclaimed water is not used for swimming, it is reassuring to know that it meets those high standards.

San Joaquin Reservoir

continued from page 1

California (MWD), the former operator of the reservoir, had proposed covering the reservoir with a floating plastic cover so that it could continue to be used for drinking water storage. However, MWD abandoned that plan due to extremely high costs. In addition, there were protests from surrounding property owners who did not want to lose a water view.

While IRWD had always been a part owner of the reservoir, it recently purchased the remaining capacity from the consortium of cities and water districts that had previously owned it jointly. Plans are now moving ahead to convert the reservoir to reclaimed water storage.

The reservoir's capacity is 3,050 acre-feet, or 994.3 million gallons. Under the IRWD plan, reclaimed water would be sent to the reservoir for storage during winter months when demand is lower. Reclaimed water would be removed from the reservoir from April through November, when demand is higher.

Increased reclaimed water use for landscape irrigation and other purposes saves both money and energy because it means that less drinking water needs to be pumped hundreds of miles from the Colorado River and Northern California.

		Michelson Plant (MWRP)			ET-1 W	
Parameter	**Limit**	**Low**	**High**	**Average**	**Low**	**High**
Organic Chemicals (mg/L)						
Acetone	NS	ND	0.025	0.013		
Bromodichloromethane	NS	0.029	0.036	0.031	ND	0.00
Bromoform	NS	ND	0.0012	0.0005	ND	0.00
Carbon disulfide	NS	ND	0.0016	ND		
Carbon Tetrachloride	NS	ND	0.0007	ND	ND	ND
2-Chloroethyl Vinyl Ether	NS	ND	ND	ND	ND	0.00
Chloroform	NS	0.036	0.047	0.040	ND	ND
Chloromethane	NS				ND	0.00
cis-1,2-Dichloroethene	NS				0.0007	0.00
Dibromochloromethane	NS	0.011	0.012	0.011	ND	0.00
Methyl Chloride	NS	ND	0.0016	0.0009	ND	ND
Trichloroethene					0.0024	0.01
Inorganic Chemicals (mg/L)						
Alkalinity as (CaCO3)	NS	101	150	127	203	203
Ammonia-N	NS	ND	2.0	ND		
Antimony	NS	0.0004	0.0031	0.0019		
Arsenic	0.05 (1)	ND	0.0029	0.0016		
Barium	1 (1)	0.024	0.057	0.040		
Bicarbonate	NS	101	150	127	203	203
Boron	1 (2)	0.28	0.59	0.5	0.21	0.21
Cadmium	0.01 (1)	ND	0.0002	ND		
Calcium	NS	37	68	49	122	122
Chloride	150 (2)	102	183	137	192	192
Chromium	0.05 (1)	0.0007	0.0041	0.0017		
Cobalt	0.2 (1)	0.0003	0.0007	0.0005		
Copper	0.02 (1)	0.0032	0.0083	0.0060		
Fluoride	1.0 (2)	0.28	0.55	0.45 (7)		
Iron	0.3 (1)	0.04	0.10	0.07		
Lead	0.05 (1)	0.0016	0.0050	0.0033		
Magnesium	NS	10.6	25.5	17.8	28.1	28.1
Manganese	0.05 (1)	0.0351	0.0705	0.0419		
Mercury	0.002 (1)	ND	0.0007	ND		
Nickel	NS	0.0054	0.0138	0.0086		
Nitrate (as N)	NS	2.9	5.5	4.5	7.9	7.9
Phosphate, Ortho (as P)	NS	0.2	2.9	1.2	ND	ND
Potassium	NS	14.3	37.3	20.0	3.5	3.5
Selenium	0.01 (1)	ND	0.0021	ND		
Silver	0.05 (1)	0.0003	0.0008	0.0004		
Sodium	125 (2)	116	142	129 (7)	135	135
Sulfate	240 (2)	110	248	163 (7)	229	229
Zinc	0.1 (1)	0.0388	0.0867	0.0666		
Additional Constituents Analyzed (Unit is mg/L except as specified)						
Biochemical Oxygen Demand	20 (1)	ND	11	ND		
Chemical Oxygen Demand	NS	12	41	23		
Chlorine residual	NS	3.2	17.1	10.0	ND (5)	0.2
Coliform Bacteria (MPN/100mL)	2.2 (3)	ND	23	ND	ND	ND
Color (CU)	NS	7	37	20	ND	9
Electrical Conductivity (umhos/cm)	NS	538	1265	892	1430	158
Foaming Agents (MBAS)	NS	ND	0.35	0.18		
Hardness as CaCO3	380 (2)	144	268	199	420	420
pH (units)	6.5 - 8.5 (1)	6.5	6.8	6.6	6.7	7.7
Suspended Solids	20	ND	4.5	1.3		
Total Dissolved Solids	720 (2)	566	812	680	920	920
Turbidity (NTU)	2 (1) (4)	0.4	2.0	1.0	0.1	0.9

NOTES:

(1) Michelson Water Reclamation Plant (MWRP) effluent limitation.
(2) Mixed irrigation limitation.
(3) Coliform limitation is a use-dependent, 7-day median of 2.2 or 23 MPN. No single sample may exceed 23 MPN.
(4) Turbidity limitation is 2 NTU, based on a daily average with no turbidity over 5 NTU for 5% of the time.
(5) Chlorine is not added to the ET-1 Well or Well 72.
(6) ILP, ET-1 and Well 72 have no turbidity limits.
(7) Limit is based on a flow-weighted average of all water sources.
Note: Monitoring requirements vary for the different sources of water. Therefore, all types of analyses are not performed on all water sources.

ABBREVIATIONS:

NS . . . . No existing standards or limitations
ND . . . . Not Detected
mg/L . . . . Milligrams per Liter
MPN/100mL . Most Probable Number per 100 milliliters
CU . . . . Color Unit
umhos/cm. . . Micromhos per Centimeter
MBAS . . . . . . Methylene Blue Active Substances
NTU . . . . Nephelometric Turbidity Units
MWRP . . . . . Michelson Water Reclamation Plant
ET-1 Well . . . TCE recovery well

erage	Irvine Lake Low	Irvine Lake High	Irvine Lake Average	Well 72 Low	Well 72 High	Well 72 Average
				ND	ND	ND
				ND	ND	ND
				ND	ND	ND
008				ND	ND	ND
				ND	ND	ND
				ND	ND	ND
015				ND	ND	ND
				ND	ND	ND
132				ND	ND	ND
				207	207	207
	0.0005	0.003	0.0018			
	ND	0.0028	0.0015			
	0.097	0.134	0.112			
				207	207	207
	0.14	0.68	0.33	0.17	0.17	0.17
	ND	ND	ND			
				145	145	145
	56	78	66	207	207	207
	0.0006	0.0026	0.0012			
	0.0002	0.0006	0.0003			
	0.0054	0.0239	0.0098			
	0.31	0.52	0.39			
	0.08	1.08	0.38			
	0.0004	0.0028	0.0009			
				35.7	35.7	35.7
	0.0238	0.1790	0.0984			
	0.0005	0.0300	0.0100			
				13.8	13.8	13.8
				ND	ND	ND
				2.5	2.5	2.5
	ND	0.0018	ND			
	ND	0.0007	ND			
	52	83	73	106	106	106
	133	249	222	186	186	186
	0.0060	0.0640	0.0270			
(5)	ND	10	1.4	ND (5)	ND (5)	ND (5)
	ND	1600	110	ND	ND	ND
	11	172	73	ND	176	10
0	845	981	924	1330	1514	1389
	298	348	326	508	508	508
	7.1	8.4	7.9	6.6	7.7	7.2
	0.8	32	9.7			
	576	668	637	1050	1050	1050
	0.5	26.5 (6)	10	0.1	35 (6)	1.7

How to read this data

IRWD collects and analyzes reclaimed water samples for Priority Pollutants, a national list of elements and compounds listed on these two pages, whose presence in wastewater has been established. Priority Pollutants have varying levels of environmental toxicity. IRWD is required to perform these analyses by regulation on a quarterly basis. **The vast majority of Priority Pollutants are not detected (ND) in IRWD's reclaimed water and are listed above right.** The few constituents that are detected are primarily associated with domestic use and disinfection practices. **Only the constituents with detectable levels are listed in the table above.**

The substances below were monitored but <u>not detected</u>:

ORGANIC CHEMICALS

Acenaphthene
Acenaphthylene
Aldrin
Alpha BHC
Alpha Endosulfan
Anthracene
Benzene
Benzidine
Benzo (A) Anthracene
Benzo (A) Pyrene
Benzo (B) Fluoranthene
Benzo (K) Fluoranthene
1,12-Benzoperylene
Beta BHC
Beta Endosulfan
Bis (2-Chloroethoxy) Methane
Bis (2-Chlorisopropyl) Ether
Bis (2-Chlorethyl) Ether
Bis (2-Ethylhexyl) Phthalate
Bromobenzene
Bromochloromethane
Bromomethane
4-Bromophenyl Phenyl Ether
Butyl Benzene Phthalate
N-Butylbenzene
Chlordane
Chlorobenzene
Chloroethane
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl Phenyl Ether
2-Chlorotoluene
4-Chlorotoluene
Chrysene
cis-1,3-Dichloropropene
4,4'-DDD
4,4'-DDE
4,4'-DDT
Delta BHC
1,2,5,6-Dibenzoanthracene
1,2-Dibromoethane
1,2-Dibromo-3-Chloropropane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
2,4-Dichlorophenol
1,2-Dichloropropane
1,3-Dichloropropane
2,2-Dichloropropane
1,1-Dichloropropene
Dieldrin
Diethyl Phthalate
2,4-Dimethylphenol
Dimethyl Phthalate
Di-N-Butyl Phthalate
2,4-Dinitrophenol
4,6-Dinitro-O-Cresol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-N-Octyl Phthalate
1,2-Diphenylhydrazine
Endosulfan Sulfate
Endrin
Endrin Aldehyde
Ethylbenzene
Fluoranthene
Fluorene
Gamma BHC
Heptachlor
Heptachlor Epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachloroethane
Hexachlorocyclopentadiene
Indeno(1,2,3-CD)Pyrene
Isophorone
Isopropylbenzene
4-Isopropyltoluene
Methyl Bromide
Methyl Ethyl Keytone
Methyl Isobutyl Keytone
Methylene Chloride
Naphthalene
Nitrobenzene
N-Nitrosodi-N-Propylamine
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
2-Nitrophenol
4-Nitrophenol
PCB 1016
PCB 1221
PCB 1232
PCB 1242
PCB 1248
PCB 1254
PCB 1260
P-Chloro-M-Cresol
Phenanthrene
Phenol
Pentachlorophenol
Propylbenzene
Pyrene
Styrene
tert-Butylbenzene
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
1,2-trans Dichloroethylene
trans-1,3,-Dichloropropene
1,2,3-Trichlorobenzene
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
Trichlorotrifluoroethane
1,3,5-Trimethylbenzene
Toxaphene
Vinyl Chloride
Xylenes, Total

Inorganic Chemicals

Beryllium
Carbonate
Cyanide
Thallium

Reclaimed Water Quality Monitoring Program at IRWD

The Water Quality Department of Irvine Ranch Water District (IRWD) samples the reclaimed water system every week.

While state regulations require IRWD to monitor the quality of the reclaimed water as it leaves the reclamation plant, sampling within the distribution system is not required by any regulatory agency. However, IRWD performs this service for the benefit of our customers and for maintaining internal standards.

A total of 18 distribution sites, three supplemental irrigation wells and four reclaimed water storage reservoirs are tested on a weekly basis. An automated composite sampler also collects the final product from the Michelson Water Reclamation Plant (MWRP) continuously throughout a 24-hour period for daily analysis.

In the field, water is analyzed for pH and total chlorine residual. Samples brought back to the lab are analyzed for total coliform bacteria, electrical conductivity (salts and minerals), turbidity (clarity), color and suspended solids. This data is forwarded to the reclamation plant and systems operations personnel to make the necessary process and/or system adjustments.

By keeping an active watchful eye on the distribution system IRWD strives to ensure a high quality product is delivered to our reclaimed water customers.

The mission of Irvine Ranch Water District, a public agency, is to provide reliable, high quality water and sewer service in an efficient, cost effective manner and environmentally sensitive way that provides a high level of customer satisfaction.

For additional information: Contact Community Relations at (949) 453-5500.

For questions about water quality data, contact Laboratory Manager Dennis Wilson at (949) 453-5835.

A Word About Recycling
Irvine Ranch Water District recycles more than just water. We print our publications on recycled papers that are also *recyclable.* We hope you'll save this report for future reference, but if you discard it, please recycle!

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Reclaimed Water News Briefs

IRWD Involved in National Studies on Reclaimed Water

Irvine Ranch Water District is participating in two national studies aimed at improving the quality of reclaimed water. Both studies are being conducted under the auspices of the American Water Works Association Research Foundation (AWWARF).

Salinity Study: IRWD is one of 14 water agencies in several Western states studying the sources of increased salinity in water. A multi-agency workgroup, along with the Water Quality Association, proposed a salinity characterization study to AWWARF. This research seeks to characterize and propose management practices for all sources of increased salinity in the sewer collection and reclaimed water systems.

Microbial Study: Along with nine other water utilities nationwide, IRWD will be the lead agency on a study of the potential for reclaimed water quality to degrade within a storage and distribution system. By using case studies, this program will develop operational guidelines to improve the overall quality of reclaimed water. IRWD already conducts extensive monitoring to ensure that our reclaimed water maintains its quality within our distribution system (see monitoring article on page 3), but our agency is always looking for ways to improve.

IRWD Continuously Improves Reclaimed Water Quality

Irvine Ranch Water District has undertaken several projects to continuously improve the quality of its reclaimed water. Among the steps taken:

- The biological nutrient removal system within the Michelson Water Reclamation Plant was converted to nitrification/denitrification. This process converts ammonia to nitrate. Nitrates are used as a source of oxygen, releasing harmless nitrogen gas into the atmosphere.The result is a better quality reclaimed water with lower turbidity levels. As a result, IRWD is already meeting more stringent quality standards that are only now being discussed by regulators for the future. It will also mean that IRWD's reclaimed water can be used for future applications such as industrial cooling towers.
- A destratification system was installed at Sand Canyon Reservoir where reclaimed water is stored. The system uses an air compressor and diffusers to circulate the top and lower "layers" of water in the lake and to increase dissolved oxygen levels. The result, again, is better quality for end users.

Water Resources Master Plan

If you're curious about future supplies of both drinking water and reclaimed water for the area served by Irvine Ranch Water District, many answers can be found in the latest edition of IRWD's Water Resources Master Plan.

The purpose of the plan is to provide a framework for future IRWD water resources planning. It estimates future land use requirements and water demands and recommends a preferred resources strategy and implementation plan.

The plan was recently recognized by the Southern California chapter of the American Public Works Association as one of its "projects of the year" for 2000. This is due to its innovative use of geographic information systems (GIS) technology to create a plan that is more reader-friendly and easier to update.

The plan can be accessed in PDF format through IRWD's Web site at www.irwd.com. Use the direct link from the home page or click on Water Service/Engineering & Planning/Master Plan.

High Rise Building Converted to Reclaimed Water

The latest addition to the IRWD reclaimed water system occurred in June 2001 when the dual-plumbed eight-story 1900 Main Street building began using reclaimed water for toilet flushing. The Irvine office tower, which houses 80 tennants, was constructed in 1999 and had been using domestic water for that purpose until the time of the conversion. The building becomes the fifth high-rise in the IRWD service area to use reclaimed water for all toilets and urinals while all sinks and other fixtures use drinking water as before.